FCF-PLN-0875

FCF Utilization Process

Fluids and Combustion Facility

Final
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Date	Signature
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FOREWORD

This document is under the Configuration Management (CM) of the Microgravity Research, Development, and Operations Contract (MRDOC) Control Board; however, any changes or revisions to the baseline version must be approved by the Microgravity Science Division (MSD) Control Board Chair.

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PREFACE

Under MRDOC, the National Aeronautics and Space Administration (NASA) is developing a modular, multi-user experimentation facility for conducting fluid physics and combustion science experiments in the microgravity environment of the International Space Station (ISS). This facility, called the Fluids and Combustion Facility (FCF), consists of two test platforms: the Fluids Integrated Rack (FIR), and the Combustion Integrated Rack (CIR). Additionally included in MRDOC are the required support efforts for Mission Integration and Operations, consisting of the Telescience Support Center (TSC) and FCF Utilization Team.

This document defines the FCF Utilization Process and answers common questions from Payload Developers (PDs) regarding the process for integrating and operating experiments; including planning and implementation of real-time operations, and all supporting activities of the payload/facility/carrier in conjunction with on-orbit operations. This document combines and replaces two previous documents: the FCF Payload Integration End-to-End Process Overview (MIP-DOC-0010) and the FCF Operations Plan (FCF-PLN-1109).

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FOR THE
FLUIDS AND COMBUSTION FACILITY**

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REVISION PAGE

FCF UTILIZATION PROCESS
FOR THE
FLUIDS AND COMBUSTION FACILITY

Revision	Date	Description of Change or ECOs Incorporated	Contractor Verification and Date	NASA Verification and Date*
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*Enter "**N/A**" if NASA approval is not required by contract.

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1.0 INTRODUCTION

1.1 Purpose

NASA Glenn Research Center (GRC) has a requirement for developing the operations and integration of the FCF and its payloads on the ISS to perform numerous microgravity investigations in combustion science and fluid physics. In order to accomplish this task, the FCF Utilization Team will define and implement integration and operations processes. The process for integrating the FCF into the ISS for on-orbit utilization has been defined in SSP 57057. Likewise, FCF Utilization that involves payload integration and operations processes has been defined by the GRC MSD to be compatible with the ISS Program process. This document has been developed to define the FCF Utilization process, and includes answers to typical questions from PDs regarding integration into and operating within the FCF. The PD is responsible for performing mission and technical integration efforts with the FCF to assure delivery of a fully functional payload system, which assures compatibility with the total system; including test facilities, FCF, and associated transportation. Elements defined by the FCF, within this document, include Payload Planning, Mission Integration, Engineering Integration, and Operations processes, as shown in FIGURE 1.

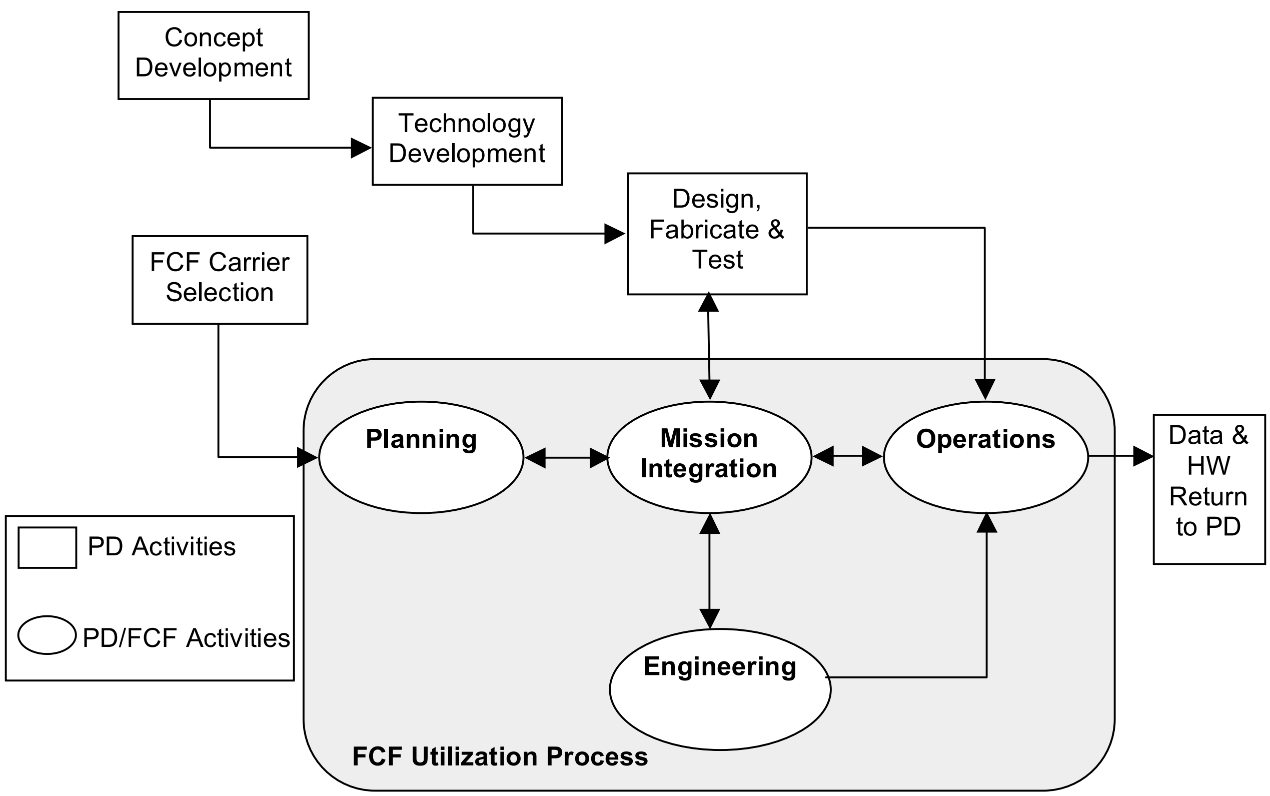


FIGURE 1 PAYLOAD DEVELOPMENT ELEMENTS

1.2 Scope

The process, defined herein, applies to all FCF payloads. This document is not intended to provide the detailed information necessary to perform specific tasks. However, it is intended to provide an introduction and address all roles and responsibilities.

Various organizational interfaces required for integration and operations are explained herein; including relationships between and within the FCF, the PD, and ISS supporting teams at Marshall Space Flight Center (MSFC), Kennedy Space Center (KSC), and Johnson Space Center (JSC). All time phases of FCF Utilization are covered including, preflight, near real-time, real-time operations, and disposal phase of the project. Dates (launch minus (L-), planning period minus (PP-) and increment minus (I-)) are provided in subsequent sections for the PDs long term planning and are typical for FCF Utilization. Actual dates are negotiated and agreed upon as part of the Integration Agreement (IA) process between the FCF Utilization Team and the PD.

Standard integration and operating procedures and documents are defined to provide consistent execution of FCF Utilization from increment to increment. Efforts described support the following: integration documentation in the format defined by the ISS Program Office (ISSPO), support of all ISS integration working groups and panels, and development of required integrated safety, operation, stowage, and training documentation. The FCF integration and operations approach recognizes that a number of multi-increment activities are going-on at the same time following various schedule templates. Many payloads also operate in a multi-increment manner. Integration processes with the ISS are streamlined where appropriate so as not to repeat unnecessary facility documentation, analysis, or products that remain the same from increment to increment.

1.3 Approach

The approach of FCF Utilization toward integrated payload operations is intended to relieve the PD of the burden of navigating through the ISS integration process. The FCF Utilization Team performs technical integration efforts necessary to assure delivery of a fully functional system (both flight and ground) that satisfies all ISS Program requirements. This is accomplished through the use of processes and tools that allow for the population of payload-unique information into standardized databases, which can then merge payload-unique requirements, with FCF hardware capabilities, into an integrated system. These same processes and tools allow for the quick and electronic dissemination of FCF integrated payload information; including data and analysis that support the ISS PROGRAM planning and manifesting processes, analytical and physical integration processes, and integrated carrier verification. This approach assures compatibility of the total FCF system with all required test facilities, the ISS, and the associated launch vehicle (Space Transportation System (STS) or other).

FCF Utilization consists of four distinct sub-processes. This document provides an overview of these sub-processes and details for application toward successful mission operations:

1. Payload Planning
   - Payload Kick-Off Meeting
     - Documents and Templates
   - Preliminary Payload Data Collection and Analysis
     - Utilization Tools
     - Payload Data Inputs
   - Payload-Unique Integration Documentation
     - IA Main Volume (MV)
       - Utilization Schedule
     - External Preliminary Interface Revision Notices (PIRNs)/Change Requests (CRs)/Exceptions
   - GRC/MSD ISS Utilization Traffic Model Analysis
2. Mission Integration
   - Integration Documentation
     - FCF IA with ISS
       - Data Sets
     - Interface Control Documents (ICDs)
     - Payload Verification Plans (PVPs)
     - Internal PIRNs/CRs/Exceptions
   - Increment Reviews
3. Engineering
   - Engineering Integration
     - FCF to Payload Compatibility Assessment
     - Ground Processing
     - Payload Testing, Reviews and Certification
     - Ground Operations
   - Sustaining Engineering
     - Logistics and Maintenance
4. Operations
   - Flight Segment Operations
   - Pre-Increment Support
     - Integrated Operations Requirements
     - Operations Product Development
     - Payload Command and Control Interfaces
     - Training
     - Data Flow
   - Increment Operations
   - Post Increment Activities

2.0 DOCUMENTS

This section lists specifications, models, standards, guidelines, handbooks, and other special publications as applicable to the FCF payload integration process.

2.1 Reference Documents

D683-27519-1	User Guide for the Payload Rack Checkout Unit (PRCU)
FCF-GPVP-FIR	FIR Generic Payload Verification Plan
FCF-IA-DS-BB	FCF Integration Agreement (IA) Data Set Blank Book Template
FCF-IA-MV-BB	FCF Integration Agreement Main Volume Blank Book
FCF-ICD-0076	FCF Software Interface Control Document (ICD)
FCF-IDD-CIR	CIR Interface Definition Document
FCF-IDD-FIR	FIR Interface Definition Document
FCF-PAH-CIR	CIR Payload Accommodations Handbook (PAH)
FCF-PAH-FIR	FIR Payload Accommodations Handbook
FCF-PLN-0031	FCF Ground Processing Plan
FCF-PLN-0033	FCF Integrated Logistics Support Plan
FCF-PLN-0655	Ground Processing Management Plan
FCF-PLN-1151	On-Orbit Procedure Development and Validation Plan
Form F4046	NASA GRC TSC Operations Support Request Form
GRC-W6000.001	Directorate Work Instruction Pre-Ship Review (PSR)
KHB 1700.7	Space Shuttle Payload Ground Safety Handbook
K-STSM-14.1-REVI-LSAH	Launch Site Accommodations Handbook for Payloads
MRD-PLN-0002	MRDOC Configuration Management Plan
MRD-PLN-0003	MRDOC Software Configuration Management Plan
MRD-PRC-0011B	ISS Exception, Preliminary Interface Revision Notice (PIRN), Change Request (CR) and FCF Exception Processes
NPD 1600.2A	NASA Security Policy
NSTS 1700.7B	Safety Policy and Requirements for Payloads Using the International Space Station
NSTS 1700.7B ISS Addendum	Safety Policy and Requirement for Payloads Using the International Space Station – ISS Addendum
NSTS/ISS 13830	Payload Safety Review and Data Submittal Requirements
NSTS/ISS 18798	Interpretation of NSTS/ISS Payload Safety Requirements

SSP 50112	ISS Operations Summary
SSP 50200	Station Program Implementation Plan
SSP 50277	Payloads Integrated Logistics Support Guidelines
SSP 50305	POIC Generic User Interface Definition Document
SSP 52000-PAH-KSC	ISS Payload Accommodations Handbook
SSP 52000-PDS	Payload Data Set Blank Book
SSP 52000-PIA-PRP	PIA BB for Pressurized Payloads
SSP 52054	ISS Payloads CoFR Implementation Plan Generic
SSP 57000	Pressurized Payloads Interface Requirements Document
SSP 57020	ISS Pressurized Payloads Accommodations Handbook
SSP 57057	ISS Payload Integration Template
SSP 57117	PIA for the Fluids and Combustion Facility
SSP 57217	Fluids and Combustion Facility Combustion Integrated Rack Hardware Interface Control Document
SSP 57218	Fluids and Combustion Facility Fluids Integrated Rack Hardware Interface Control Document
SSP 58700	ISS U.S. Payload Operations Data File Management Plan
SSP 58700-ANX5	Payload Display Implementation Plan
SSP 58309	Payload Training Implementation Plan (PTIP)
TSC-DOC-016	Telescience Support Center Operators Manual
TSC-DOC-021	Telescience Support Center Training Manual

3.0 INTEGRATED FCF SYSTEM

The FCF is a modular, multi-user facility created for installation in the ISS United States Laboratory (US Lab) Module to support microgravity fluid physics and combustion science experiments. The FCF system consists of both a Flight Segment and a Ground Segment. The Flight Segment consists of two powered racks plus sufficient on-orbit stowage in the ISS for FCF and payload hardware. The Ground Segment is required for successful integration and operation of experiment hardware and software in the Flight Segment.

The FCF three-tiered solution for accommodating a diverse complement of science requirements is shown in FIGURE 2. Multi-use experiment hardware (also referred to as a “mini-facility”) is defined as an insert or attachment to the FCF that accommodates a series of science experiments. Multi-use experiment hardware typically augments FCF standard capabilities with unique power, avionics, heat rejection, illumination, measurement, and diagnostics capabilities required by multiple Principal Investigators (PIs). Examples of multi-use experiment hardware for FCF include the Multi-User Droplet Combustion Apparatus (MDCA) for the CIR and the Light Microscopy Module (LMM) for the FIR. PI-unique hardware can either be designed to operate within existing multi-use experiment hardware or as a stand-alone experiment that operates independent of multi-use experiment hardware.

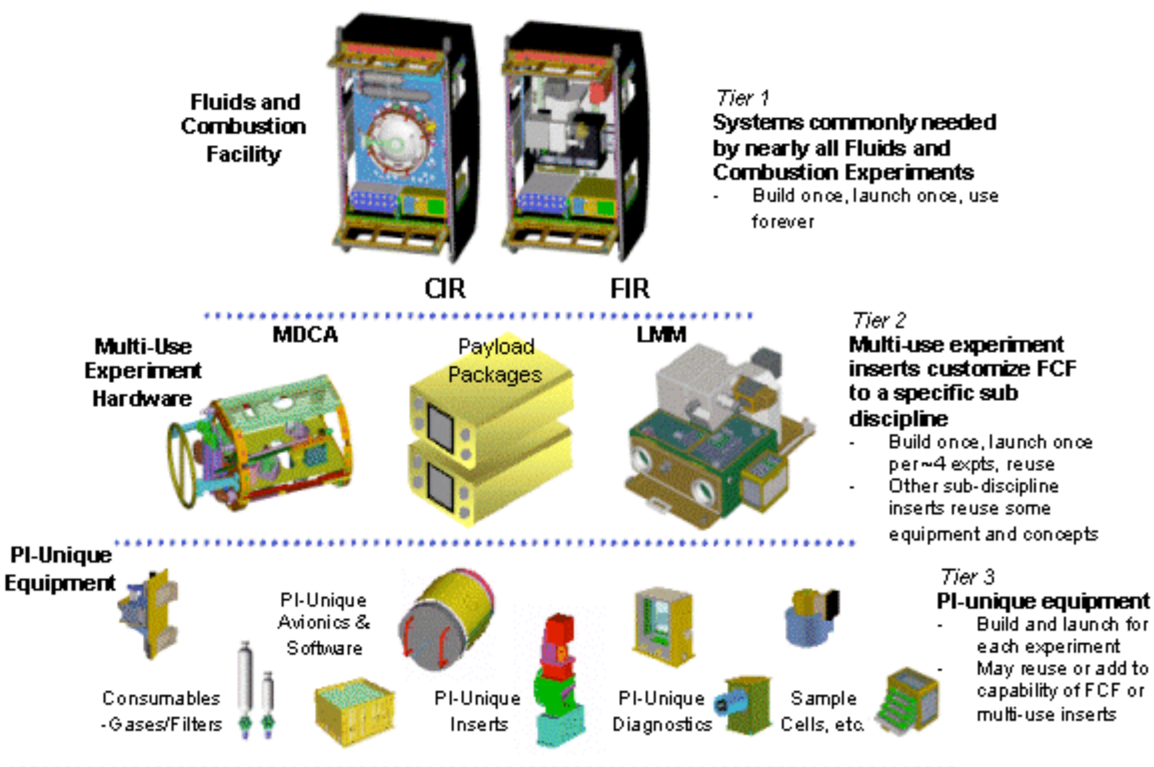


FIGURE 2 FCF 3-TIERED SOLUTION FOR SCIENCE REQUIREMENTS

FCF Utilization applies to two payload types. The first payload type includes PI-unique hardware that is integrated directly with an FCF rack (Tier 3 to Tier 1). The second payload type includes multi-use experiment hardware that is integrated directly into an FCF rack and may support multiple instances of PI-unique hardware (Tier 2 to Tier 1). It is the responsibility of the individual multi-use experiment hardware PD (Tier 2) to integrate (consolidate) any PI-unique hardware (Tier 3 to Tier 2) prior to following the processes defined within this document (Tier 2 to Tier 1).

4.0 FCF UTILIZATION ORGANIZATIONAL STRUCTURE

The ISS and FCF operate continually on an increment basis that differs significantly from the way the GRC MSD implemented on-orbit scientific studies during the shuttle era. Utilization and operations on the ISS require an organization driven by process development and implementation toward the following:

- Advocacy (manifesting, resource allocation)
- Efficiency (budget constraints, shortened schedules)
- Consistency (requirements, deliverables)

A standard method of doing business with the ISSPO is necessary to ensure all ISS Program and FCF integration and operations requirements are obtained, understood and addressed.

4.1 Payload Developer

The PD that builds experiments to be flown as part of the FCF defines their own organizational structure, and is typically composed of a Payload Operations Team, a Hardware Development Team, and a Software Development Team. The PD interfaces with the PI to perform experiments defined by the PI. PIs are scientists who define the science to be performed in the FCF. PIs directly interface with the PD for development of their experiment-specific hardware and software and for data analysis following on-orbit experiment runs. The PD develops the experiment-specific hardware and software and, using the FCF, performs the PI's experiments. Multiple PDs can be involved in one increment.

4.2 FCF Utilization Team

The FCF Utilization organization shown in FIGURE 3 provides for both the multi-increment functions and infrastructure complemented by the assignment of Increment-specific teams assigned out of the organization in support of continual FCF operations. The FCF Utilization Team interfaces with the PD, the GRC NASA Management Team, the Space Shuttle Program and the ISS Program.

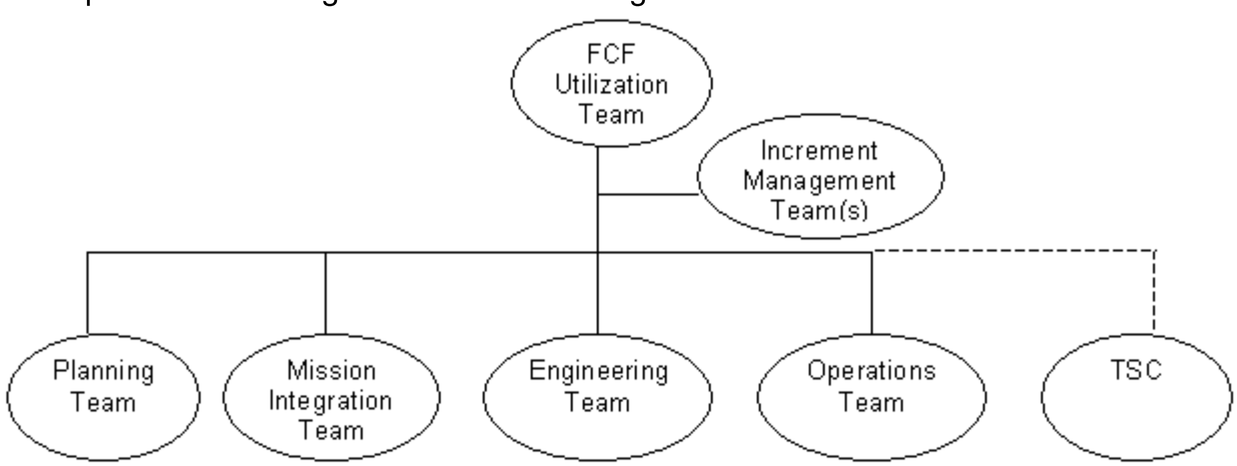


FIGURE 3 FCF UTILIZATION ORGANIZATION

The FCF Utilization Team implements the processes defined within this document for integrating payloads into the FCF and integrating and then operating the integrated FCF on the ISS. The FCF Utilization Team organizational structure mirrors the support processes described within this document including Planning, Mission Integration, Engineering and Operations with operations infrastructure support from the NASA GRC TSC. This division of responsibilities allows for process-based support of both multi-increment and increment activities.

4.2.1 Planning Team

The Planning Team is part of the FCF Utilization Team, as shown in FIGURE 4, and supports ISS Program strategic and tactical planning activities including multi-increment activities that lead to manifesting on a particular increment. Specifically, this team collects and manages payload-planning data, submits payload data to the ISSPO and assesses the GRC Resource-Based Traffic Model. This team starts their work at approximately L-54 months and provides initial planning data to the Mission Integration Team as a payload develops beyond the conceptual phase.

The Planning Lead is responsible for interfacing with the ISS Program and providing data as needed. Each payload will have a Payload Liaison assigned to help with the payload data collection activities including: requesting payload data from PDs, updating existing payload data, explaining to the PDs the data request tools, features and use of the payload data collection system, updating the payload data collection system with ISS resource allocations, responding to JSC/OZ and/or GRC requests for planning data updates, submitting data to JSC/OZ and/or GRC, and adding new payload data to the payload data collection system. As a result of these activities, an IA and schedule is signed between the PD and the FCF Utilization Team. The planning activities include comparing the payload resource requirements against the ISS allocations, which allows for an assessment of the GRC/MSD ISS Utilization Traffic Model.

The Planning Team is responsible for implementation of the external PIRN, CR, and ISS/FCF Exception review process that consists of tracking and review for the GRC payload community. As part of the process, the Planning Team provides coordination and submittal of all GRC comments for proposed document changes. This consists of maintaining a list of applicable PIRNs, CRs, and ISS/FCF Exceptions, selecting reviewers, assembling technical, cost and schedule comments, and submitting impacts to the appropriate NASA program offices.

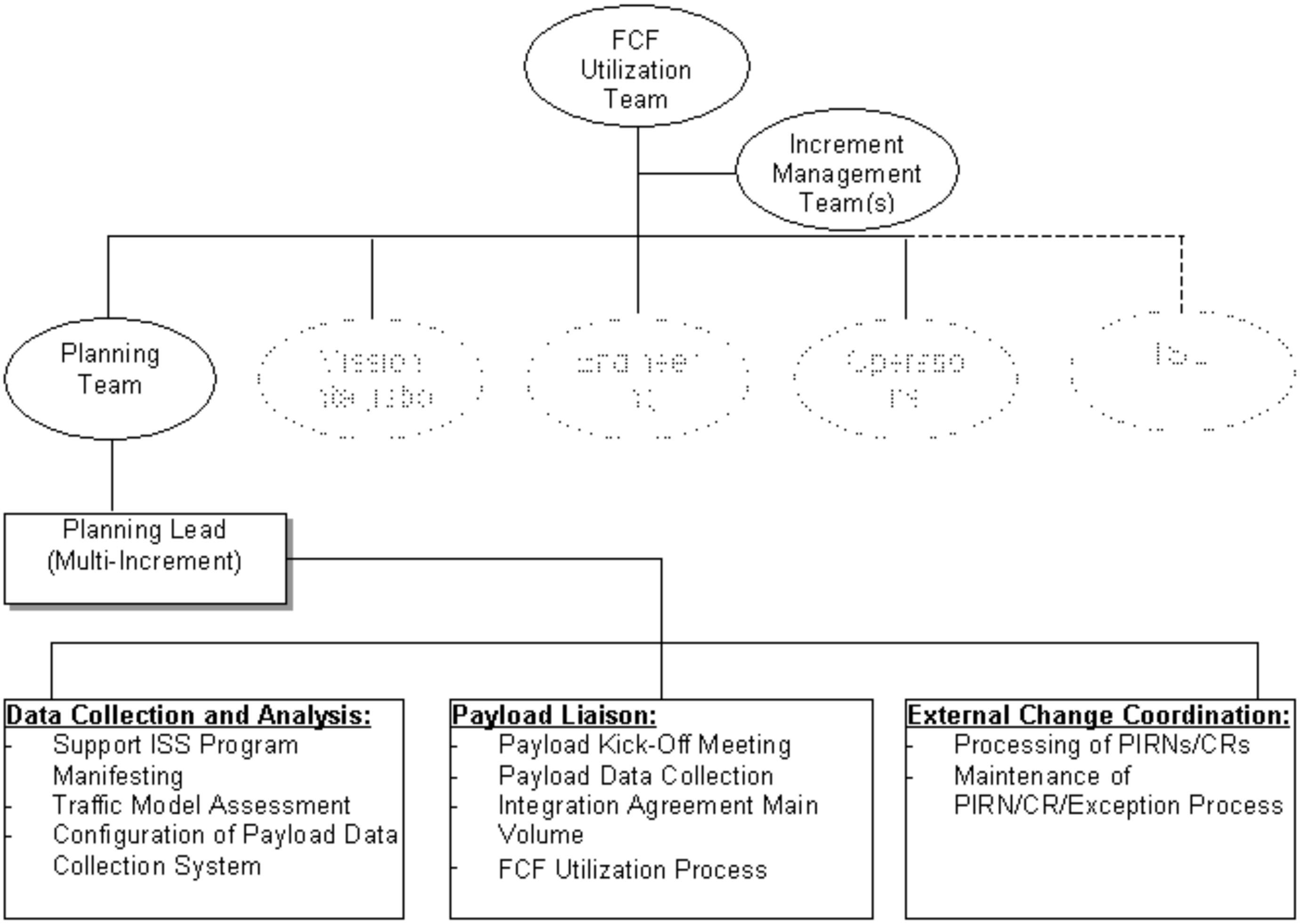


FIGURE 4 PLANNING ACTIVITIES

4.2.2 Mission Integration Team

The Mission Integration Team is part of the FCF Utilization Team, as shown in FIGURE 5. As a counterpart to the Payload Integration Manager (PIM) role on the ISS Program side, this team serves to orchestrate integration and operations activities within the FCF and from the FCF into the ISS. Specifically, the Mission Integration Team serves as an advocate to FCF and ISS groups for the payload and coordinates and facilitates meetings and reviews. Increment-specific personnel from this group, such as the Increment Manager and the Rack Integration Lead, along with the Payload Liaisons, support these payload activities.

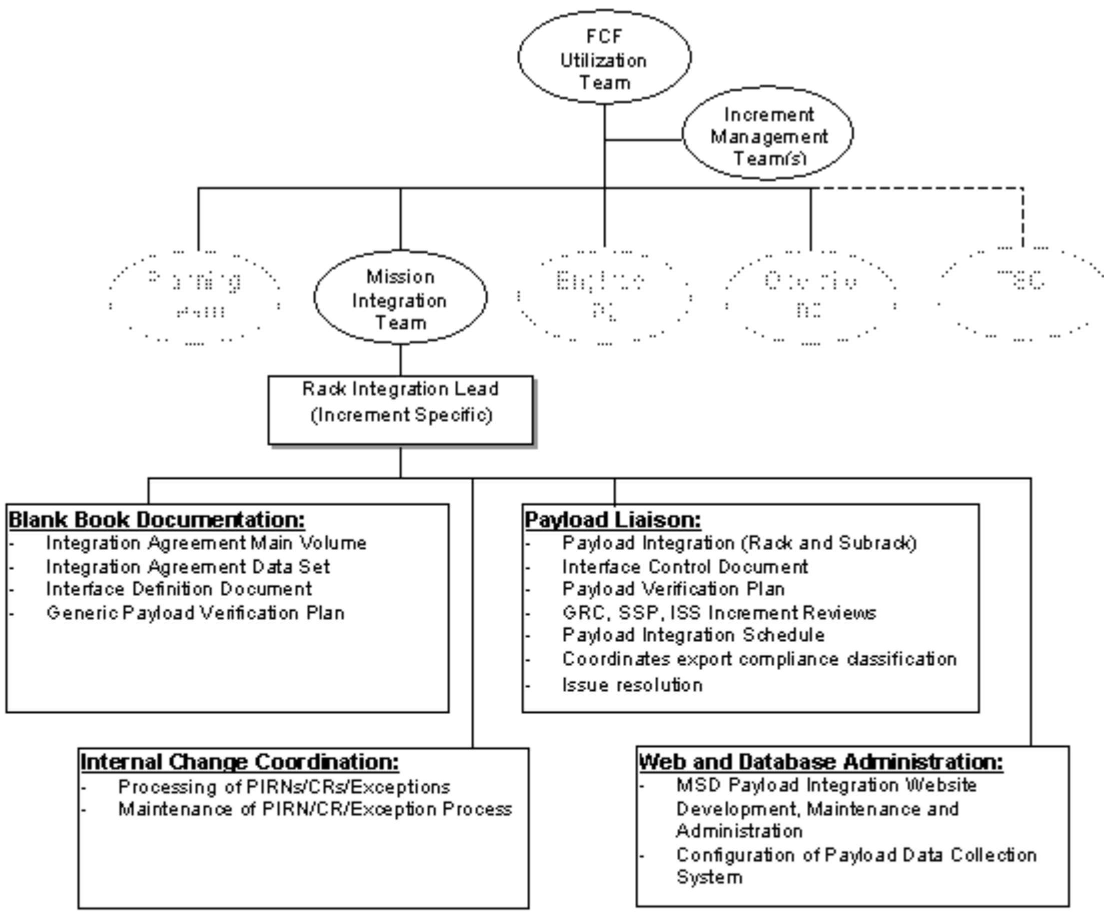


FIGURE 5 MISSION INTEGRATION ACTIVITIES

4.2.3 Engineering Team

The Engineering Team is part of the FCF Utilization Team, and performs analytical and physical integration and sustaining engineering functions. The Engineering Team works with the PD for verification of hardware and software checkout, including ground processing (analytical and physical integration); performs KSC ground processing; trend analysis and data archiving for the Engineering Development Unit (EDU) and Ground

Integration Unit (GIU); and trains the FCF Ground Support Personnel (GSP) on all ground procedures; and performs sustaining engineering.

The following payload Data Set inputs are prepared and maintained by the Engineering Team:

- Payload Configuration Data Set
- Command and Data Handling Data Set
- KSC Support Requirements Data Set.
- KSC Technical Requirements Data Set

4.2.3.1 Sustaining Engineering Team

Sustaining Engineering is part of the Engineering Team, as shown in FIGURE 6, and ensures that flight hardware and Ground Support Equipment (GSE) built or procured for the FCF continues to meet program technical, schedule, safety, and performance requirements throughout the life of the hardware and its use by the GRC. Sustaining engineering involves maintenance, repair, reconfiguration, logistics, and new hardware and software development for all ground and flight hardware and software.

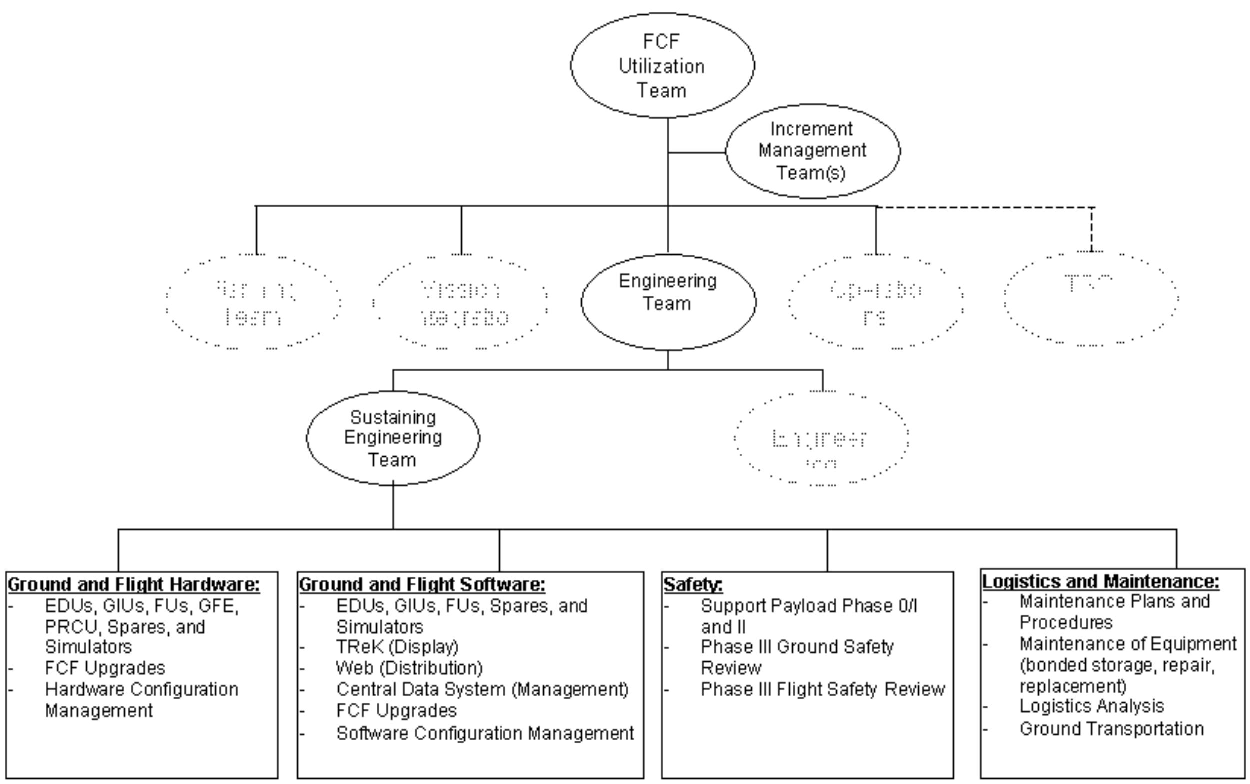


FIGURE 6 SUSTAINING ENGINEERING ACTIVITIES

The Sustaining Engineering Team is responsible for the on-going maintenance support of all FCF flight hardware, including upgrades, and ground support hardware, and the EDUs; any Training hardware and software; the GIUs; GSE used in the ground processing facility (B333 at GRC); and all hardware and software systems and components in the TSC that support on-orbit payload operations. The Sustaining Engineering Team is responsible for providing software updates, which may be needed to correct software faults, work around hardware failures, or nominal upgrades to provide additional system capabilities.

The FCF safety hazard analysis is performed by the Sustaining Engineering Team to identify hazards and mitigation methods to assure that the proposed design does not violate any safety requirements that could endanger human life or mission success. The Sustaining Engineering Team supports development of the PD's Flight and Ground Safety Hazard Reports and Phase 0/I and Phase II Safety Compliance Data Packages and the specific Phase 0/I/II reviews. The Sustaining Engineering Team provides assurance that the integrated system (FCF and payload) meets all FCF and ISS Program safety and verification requirements for the Phase III Safety Compliance Data Package. Furthermore, they assure that all hazards that must be controlled by operational means are properly implemented in crew procedures, flight rules, or training, and conduct the Phase III Safety Review with the appropriate Flight and Ground Safety Panels.

The Sustaining Engineering Team conducts appropriate analyses, data evaluations, and ground tests to maintain existing flight systems as well as developed ground systems. This includes the tracking of limited life items for safety and/or mission assurance reasons, incorporating upgrades as required, standard reporting of the on-orbit payload performance, and developing trend analyses using on-orbit systems reports and other available data. The Sustaining Engineering Team conducts logistics planning, logistics analyses, supply support operations, perform maintenance operations, develop and maintain ground procedures and execute ground transportation operations.

4.2.3.2 Engineering Integration Team

Engineering Integration is part of the Engineering Team as shown in FIGURE 7. The Engineering Integration Team provides the facilities, including the EDU, GIU, and the FCF Component Simulators, to the PD for hardware, software, and procedure development and verification. Verification data is provided through the Engineering Team's integration function. The Engineering Integration Team clearly identifies to the PD where, how, and when each function and performance requirement is verified in the verification program, before launch and, if applicable, on-orbit. The Engineering Integration Team is responsible for all compatibility, interface, and verification tests between the FCF and payload hardware and software, and is responsible for scheduling, installation, checkout and verification of the payload hardware and software through ground simulator EDU and GIU. The Engineering Integration Team provides the necessary support for proper integration of the payload hardware into the ground units and the performance of integrated verification and validation tests based on the payload-unique Verification Plan, which may include system testing, mission simulations, and ground/flight end-to-end testing. The Engineering Integration Team provides the PD with sufficient personnel support, training, and training materials on the use of FCF hardware.

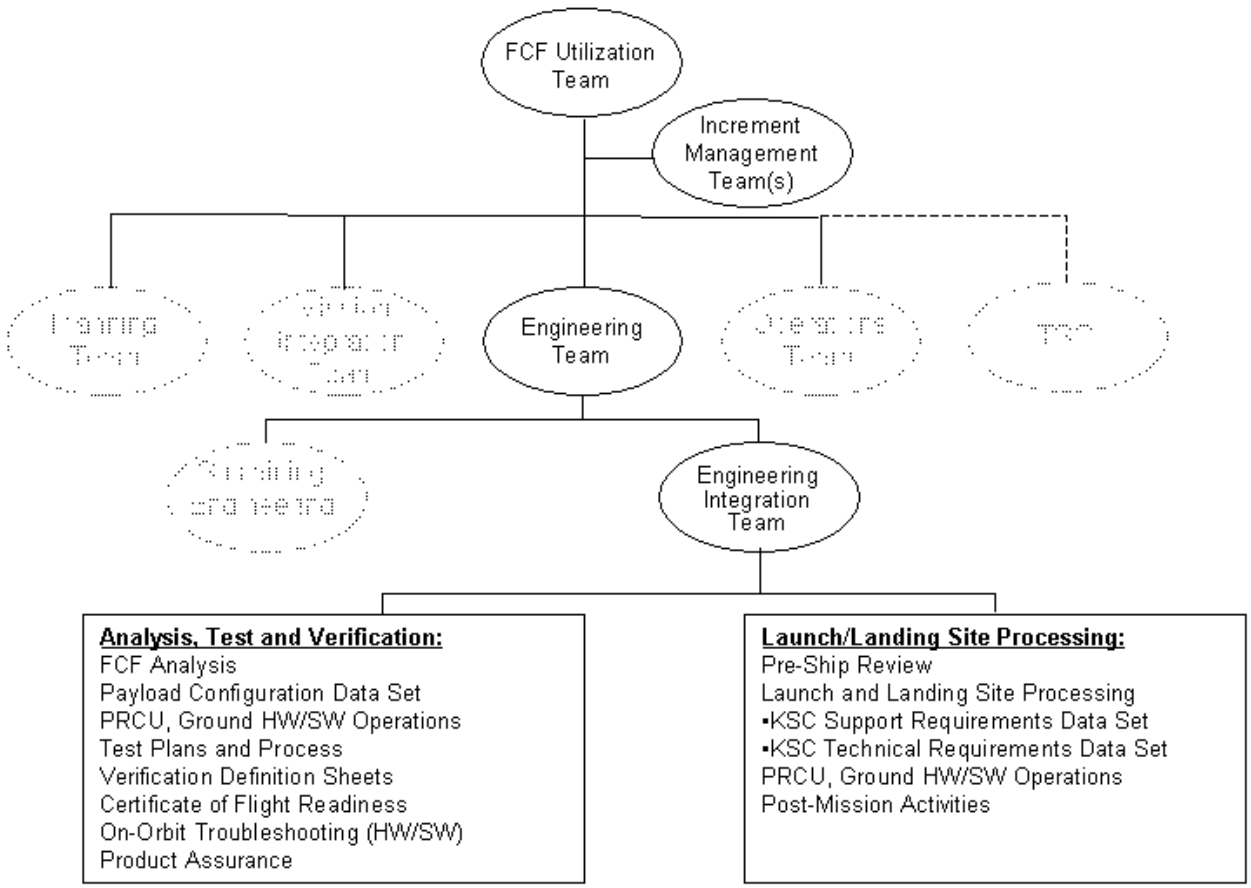


FIGURE 7 ENGINEERING INTEGRATION ACTIVITIES

The Engineering Integration Team is responsible for all ground servicing at the FCF integration and launch site, and ensures the successful integration of all payload hardware with the FCF and/or transportation system. Additionally, this team implements launch site operations and test procedures for the payload hardware and supports the development of the requirements for testing, servicing, and facility services, as required to process the payload hardware through carrier integration and pre-launch activities. They monitor tests, evaluate test data, maintain records problems, and ensure the payload hardware has been properly tested. The Engineering Integration Team participates with the KSC launch processing team activities and shall add/modify requirements, concur on procedures, analyze data, make engineering recommendations and decisions required by conditions not within specifications, and provide other information required for launch site support as applicable.

4.2.4 Operations Team

The Operations Team is part of the FCF Utilization Team as shown in FIGURE 8. The Operations Team assists the PD with generating payload operations procedures and displays, and then develops FCF increment-specific products for the ISS. This team performs crew training and FCF GSP training for real-time operations. The Operations Team performs real-time operations from the TSC and performs trend analysis and data archiving of flight data.

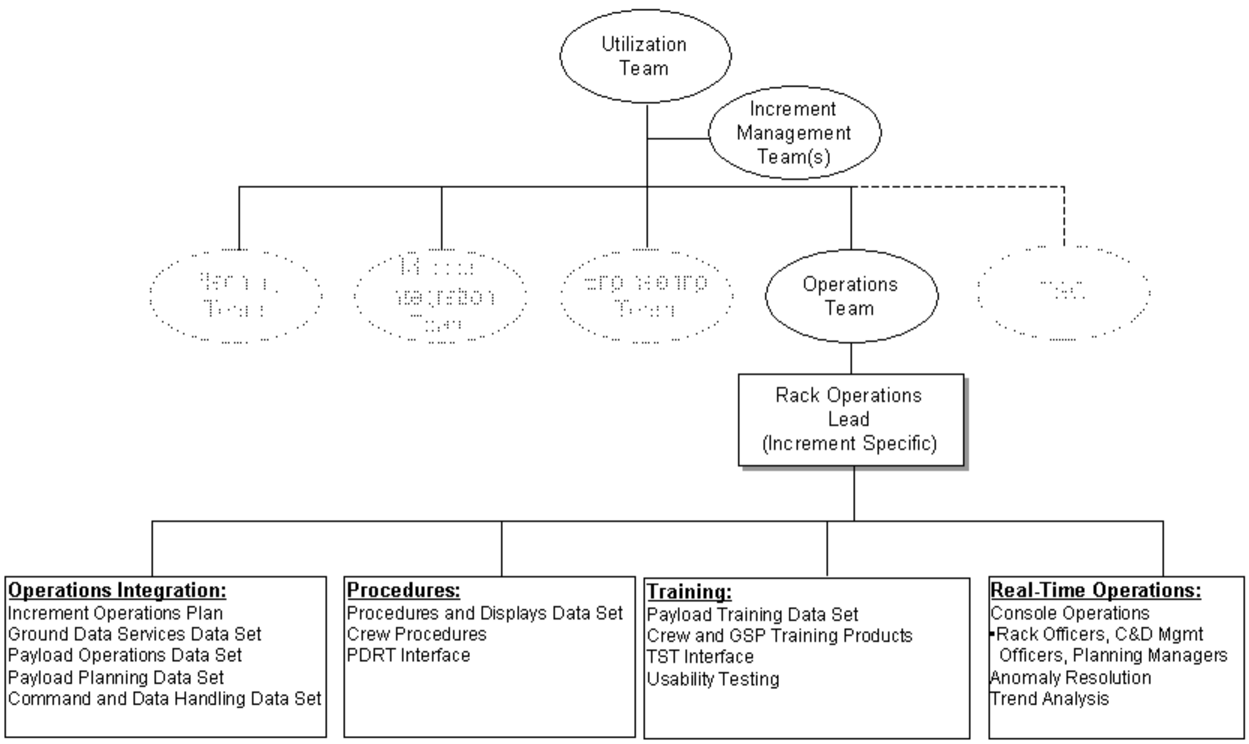


FIGURE 8 OPERATIONS ACTIVITIES

The Operations Team develops and maintains the internal increment operations plan and develops and performs the Data Set management function for the following increment-specific integrated payload Data Sets:

- Payload Training Requirements Data Set
- Ground Data Services Data Set
- Payload Operations Data Set
- Payload Planning Data Set
- Procedures and Displays Data Set

4.2.5 Telescience Support Center Team

The TSC Team supports the FCF Utilization Team, as shown in FIGURE 9, and supports all NASA GRC MSD payloads including the FCF and is responsible for both the day-to-day operations and maintenance of the TSC. The TSC Team's management of the TSC facility includes requirements development, capability development, and test and verification of the system, updating facility configuration for new payload teams, establishing and maintaining a system to allow for distributing and archiving science data, and troubleshooting TSC to Payload Operations and Integration Center (POIC) and TSC to payload team network and interface problems. Additionally, this team conducts technical interchange meetings, requirements reviews, and readiness reviews, and assists PDs in the development, documentation, and implementation of increment-specific telescience requirements. The TSC Sustaining Engineering Team has specific responsibilities to track system configuration, backup all data, perform anti-virus software maintenance, apply operating system patches and upgrades, monitor mission network Health and Status, and maintain TSC infrastructure hardware. The TSC Team provides for the delivery of telemetry data to payload-specific hardware located at the TSC facility.

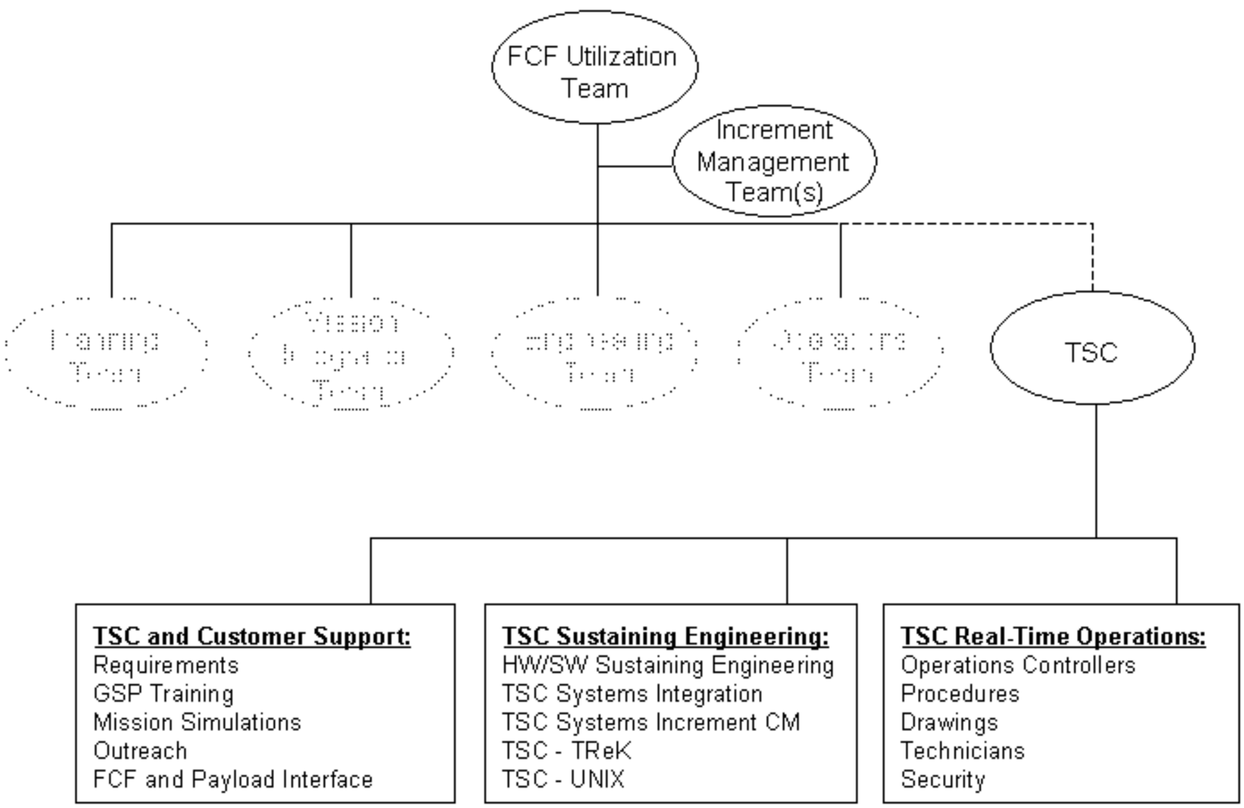


FIGURE 9 GRC TELESCIENCE SUPPORT CENTER ACTIVITIES

The TSC Team operates and maintains the TSC facility, workstations and Telescience Resource Kits (TreKs), and support systems for GRC and remote user locations. They are responsible for the physical and automated information systems security for the TSC facility. This team assists PDs in integrating increment-specific hardware into the TSC and provides administration and maintenance support of all hardware located at the TSC.

The TSC Team develops and conducts training courses and simulations to demonstrate the use of TSC capabilities and assure the proficiency of console operators either at the TSC or at remote sites. The TSC Team is responsible for supporting the certification and operational readiness of the system and operators that support FCF Utilization.

4.3 Increment Team(s)

An ISS increment-specific management role is required to integrate subsystem and diagnostic-specific functions at an FCF level for single submittal to the ISS Program for ISS increment operations. In support of the PD, FCF and ISS Program flight-specific requirements, an Increment Team, as shown in FIGURE 10, is established for each FCF Increment manifested on the ISS. The Increment Team is lead by an Increment Manager assigned from the Mission Integration Team and is supported by a Rack Integration Lead also assigned from the Mission Integration Team and a Rack Operations Lead assigned by the Operations Team. The Increment Team is responsible for the design, development, test, performance, and safety of the integrated FCF payload and GSE as well as for providing support to the ISS/US Lab analytical and physical integration activities. This team interfaces with the ISS Payload Integration Manager (PIM) to accomplish the analytical integration of the FCF and/or its payloads into the ISS Carrier.

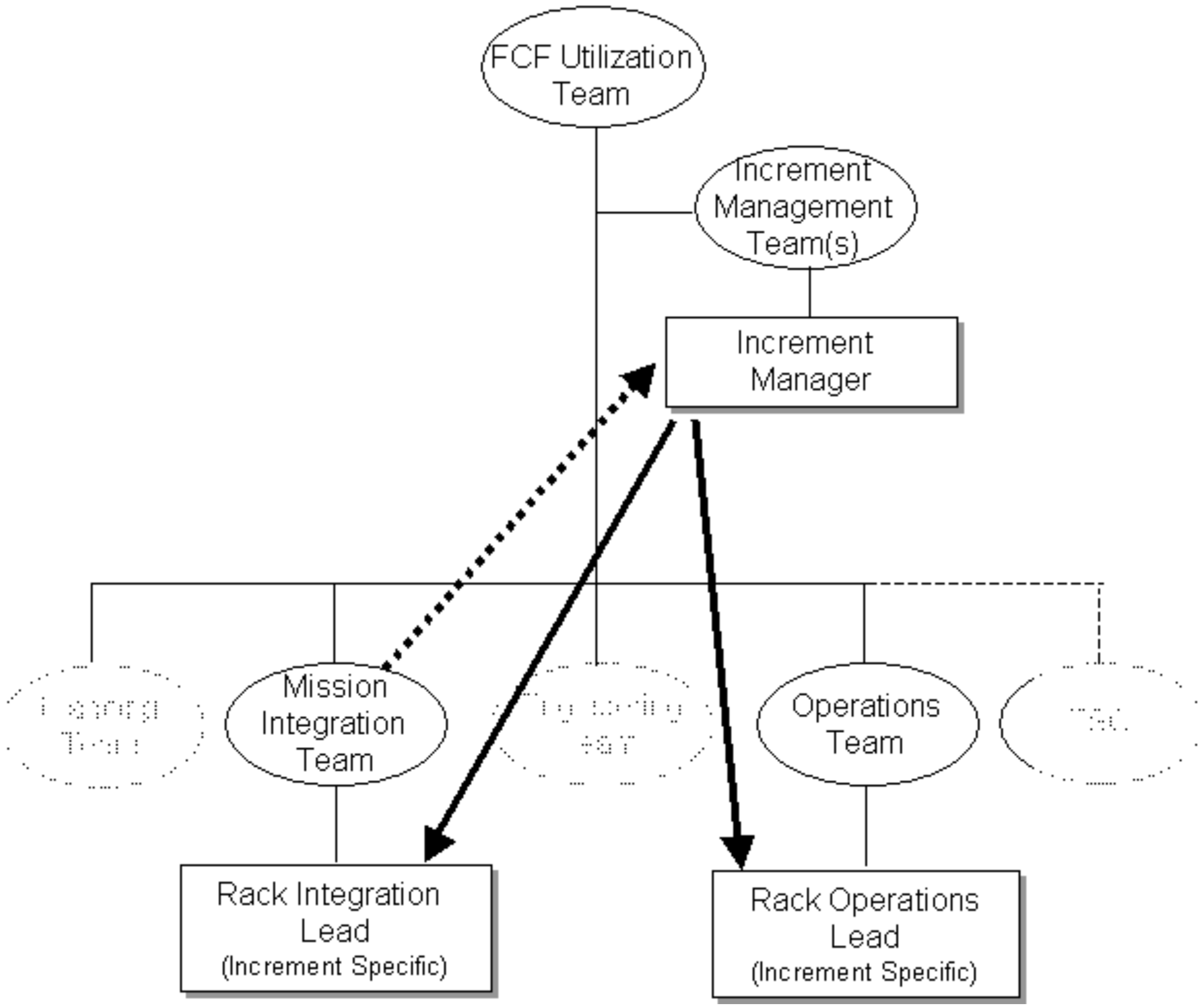


FIGURE 10 INCREMENT TEAM(S)

In order to maximize the science return, the Increment Team performs various functions (physical, analytical, operational), as described within this document. Activities may include multiple science investigations within a given time period in the FCF. The Increment Team operates as shown in FIGURE 11.

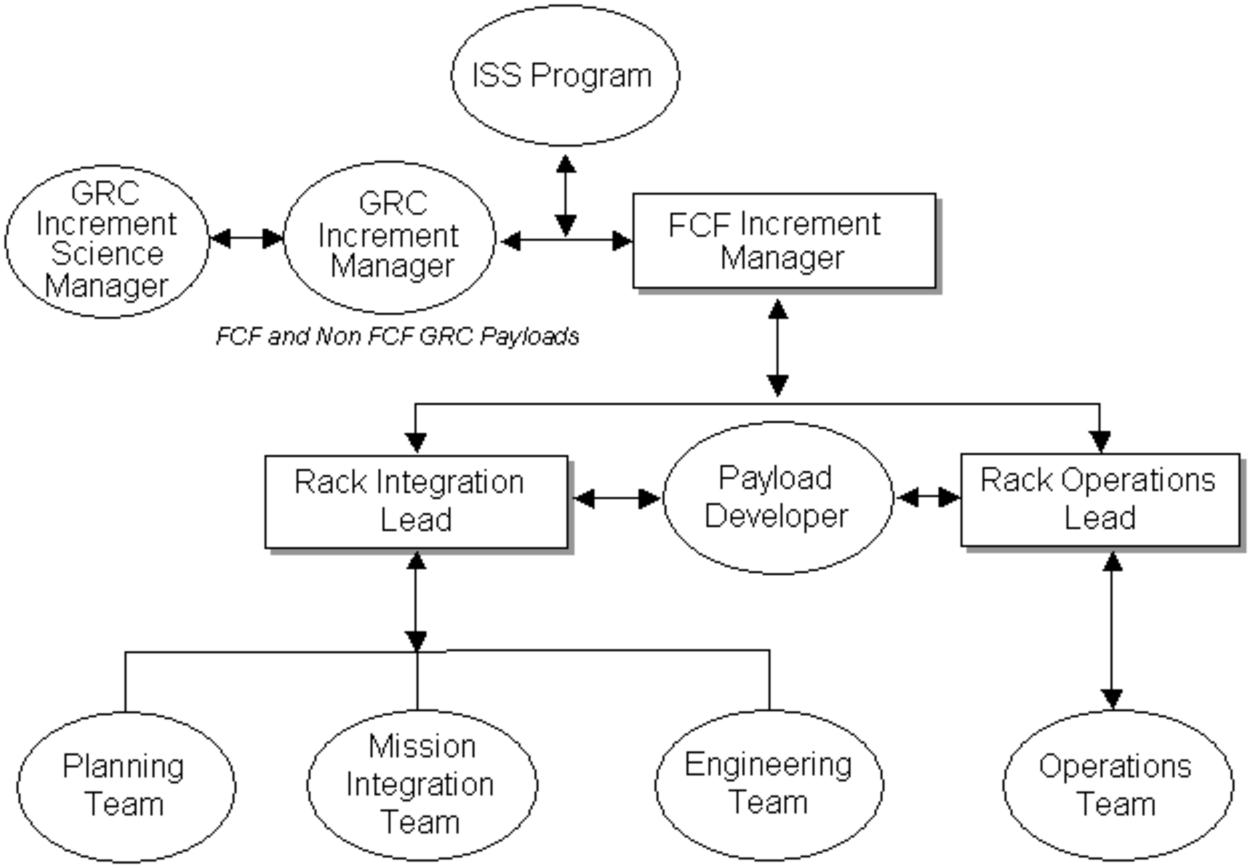


FIGURE 11 INCREMENT TEAM COORDINATES FCF UTILIZATION ACTIVITIES

The Increment Team functions to coordinate the unique expertise and necessary manpower to support planned test and checkout, alignment, and calibration activities. They provide ICD data, drawings, models, reports, and analyses as defined by the ISS Integration Process in SSP 57057. The Increment Team focus includes the rollup of both FCF and multi-payload activities for a given increment-specific integrated payload. This team is responsible for integrating payload mission data handling and processing requirements and for identifying to the ISS Program all payload problems that may affect ISS milestones. The Increment Team documents and provides requirements for increment-specific payload ground operations, services and facilities to the KSC launch site and is responsible for coordinating the overall delivery of the increment payload(s) to the launch site, and support any required receiving inspections. In addition, the Increment Team develops payload flight and flight support requirements, and provides payload crew activity plans and payload procedures, which are utilized to develop ISS crew timelines. The Increment Team, through the Rack Operations Lead, is responsible for coordinating the integrated crew training on in-flight FCF and payload procedures and operations.

The Increment Team consists of the following personnel with the following defined roles and responsibilities:

- GRC Increment Manager
  - Responsible for all FCF and non-FCF GRC payloads on a given increment
  - Primary point of contact for Increment Manager and GRC Increment Science Manager
- GRC Increment Science Manager
  - Prioritizes science activities
  - Coordinates with GRC Science Representatives
- FCF Increment Manager(s)
  - Manages and reports on the overall increment
  - Responsible for overall Increment budget and schedule
  - Negotiates and coordinates documentation of agreements as well as integration data deliveries such as:
    - Resource requirements
    - IA MV, Integration Schedule, ICD, PVP, Data Sets
    - Schedules and coordinates approval of all integrated increment deliverables
  - Primary point of contact to the ISS PIM
    - Overall responsibility for increment-specific deliverables to the ISS Program
  - Conducts increment reviews
  - Coordinates, tracks, and provides the status on completion of open work
  - Supports PD safety process
- Rack Integration Lead(s)
  - Provides detailed technical guidance in the area of FCF interface and integration
  - Provides increment analysis to provide roll-up (i.e. summations, timelines, etc.) of data to FCF rack-level and, with approval from the PD and the Increment Manager, submits data to the ISS Program.
  - Identifies and coordinates all FCF planning and integration activities and deliverables (single point of contact for PD)
    - Lead monthly meetings with the PD to address integration issues.
    - Work with the PD to resolve any technical issues identified.
    - Attend weekly PD meetings as required.
    - Support PD Design Reviews
    - Generate and maintain integration documentation based on PD (or multiple PD) inputs
    - Multiple Payload Liaisons may be assigned depending on the number of experiments on a given increment to support the Rack Integration Lead(s)
  - Supports increment reviews
  - Supports PD safety process
    - Assists PD in preparation of Safety and Verification Packages
  - Supports the coordination of EDU and GIU utilization for integrated testing
    - Responsible for the scheduled use of the GIU by the increment payloads.
  - Supports FCF Integration and Checkout

        - FCF GRC Ground Processing (Analytical & Physical Integration)
- Rack Operations Lead(s)
    - Performs operation integration activities in preparation for real-time operations
    - Develops FCF increment-specific procedures
    - Generates integrated operations displays
    - Performs GSP and Crew Training
    - Performs Mission Operations (leads the rack operations cadre)
    - Coordinates rack activities with the POIC, PD, Increment Manager and rest of Cadre
    - Serves as single point of contact with MSFC POD
    - Supports increment reviews
    - Supports PD safety process

4.3.1 Operations Cadre

The Operations Cadre evolves from the Increment Team and is composed of the Payload Operations Team and the Operations Team, as shown in FIGURE 12. This team supports and performs real-time operations. Real-time operations include monitoring and controlling the FCF Flight Segment from TReK workstations in the GRC TSC. The Operations Cadre is formed to conduct increment operations and consists of payload, FCF, and TSC provided personnel to support successful mission operations dependent on a particular increment's payload requirements.

The Operations Cadre is on-console during all FCF on-orbit operations. It is anticipated that the PD will be on-console during experiment operations (not necessarily down-linking operations). The Rack Operations Lead and Planning Manager are assigned by increment, and transition from preparation phase to console operations. The FIR and CIR Rack Operations Lead and Command and Data Officers perform console operations, independent of increment. Cross training of FIR and CIR Rack Operations Leads and Command and Data Officers is implemented for dual redundancy while on-console. The FIR and CIR Rack Operations Leads and Command and Data Officers roll off console operations and into other areas (operations preparation), on 3-6 month rotational assignments to reduce burnout and provide personal career development.

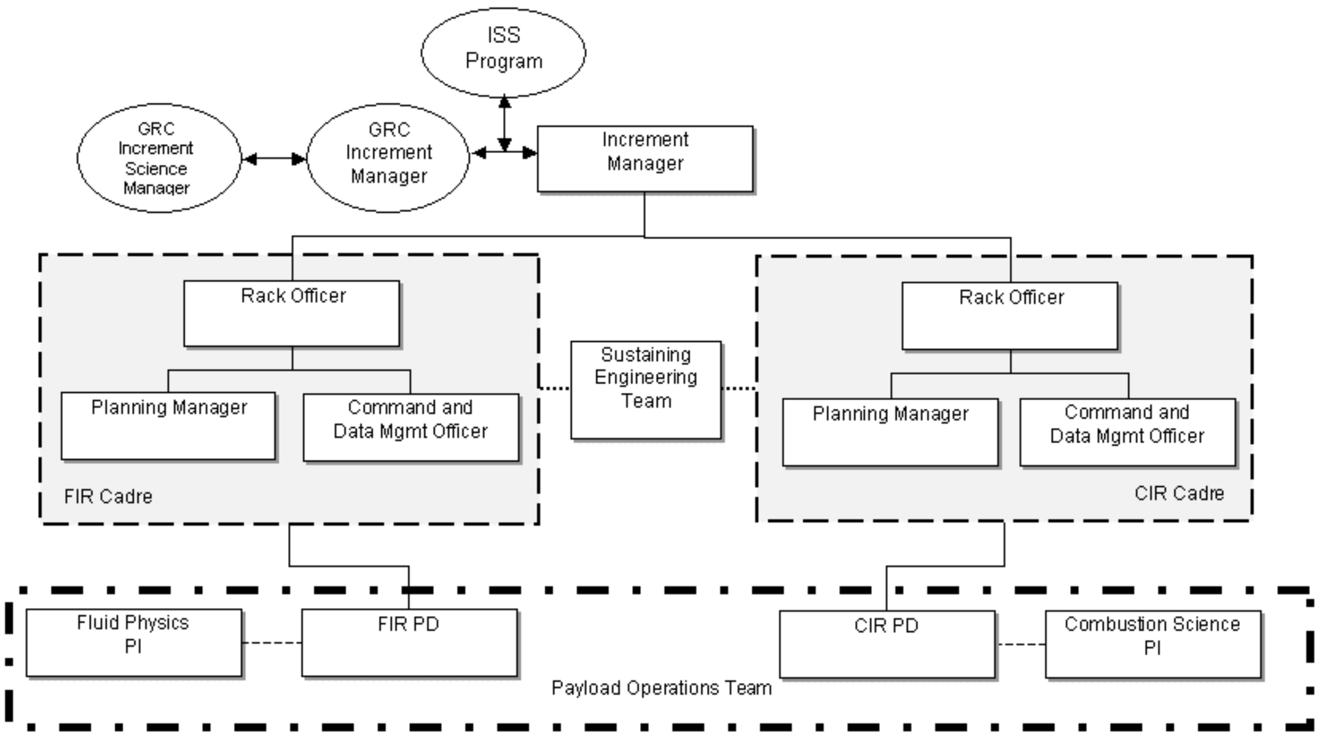


FIGURE 12 OPERATIONS CADRE

The Operations Cadre consists of the following personnel with the following defined roles and responsibilities:

- Increment Manager
  - Receives continued support from Increment Team
  - Represents FCF to ISS Increment Science
  - Resolves conflicts between CIR and FIR Operations
  - Transitions unfinished science to future increments
  - Not a full-time console position.
- Rack Officer
  - Receives continued support from Increment Team
  - Coordinates rack activities with the POIC, PD, Increment Manager and rest of Cadre
  - Serves as single point of contact with MSFC POD
  - Authorizes submission of reports, Operations Change Requests (OCRs), data requests, etc to Payload Operations Integration Function (POIF)
  - Makes decisions regarding rack operations, based upon inputs from Planning manager and Command and Data Manager, and PD Operations Lead

   - CIR and FIR Operations Leads are the FIR and CIR Rack Officer (RO) on primary shift who handle the generation and submission of all OCRs for their respective racks by working with their PDs for required inputs
   - CIR and FIR Operations Leads are designated on an increment basis, and follow the increment through preparation phase to execution
- Command and Data Management Officer(s)
   - Monitors and evaluates the data down-linked from FCF to ISS
   - Verifies all data down-linked is received and complete, including science data generated with rack resources
   - Re-initiates downlink if necessary
   - Sends commands per ROs directions
   - Serves as Data Management Controller (DMC) and Command and Payload Multiplexer-Demultiplexer (MDM) Officer (CPO) interface
   - Provides data to PDs for post processing, inclusion in the Central Data System (CDS) and the PD's web site Data Set
- Planning Manager(s)
   - Tracks resource usage (gas availability, power, thermal, calibration, data)
   - Replans rack operations, based upon inputs from PD and resource availability
   - Maintains increment Operations Plan daily
   - Serves as Timeline Change Officer (TCO) Interface
   - Schedules rack maintenance, hardware calibration, and replenishment of consumables based upon inputs from sustaining engineering, user's guides, design information, etc.
   - Verifies rack data resources are sufficient to capture the anticipated science data
- Sustaining Engineering
   - Performs trend analysis on Flight Hardware, GIU and EDU
   - Provides inputs to real time safety decisions
   - Makes recommendations for maintenance and off-nominal situations
   - Remains on-call for FCF anomaly resolution
      - Electrical, thermal, mechanical, structural, software, etc.
- PD Operation Team(s)
   - Supports on-orbit integration activities, experiment operations, troubleshooting, maintenance and deinstallation activities
   - Plans for, and replans as necessary, experiment runs and coordinates with Planning Manager
   - Evaluates real-time data, manages science data distribution to PI's (web) and archive science data
   - Commands PI-specific hardware, after enabled by FCF Command and Data Officer, per-increment operations plan
   - Represents PI to FCF

5.0 PAYLOAD PLANNING

Payload Planning includes the initial collection and management of payload data (planning data inputs), resource guideline development, and multi-increment/increment planning that, upon completion, results in the payload being manifested on a particular ISS increment or increments.

The primary activities and/or products of the Payload Planning process are summarized below and shown in FIGURE 13:

- Payload Kick-Off Meeting at L-48 months
- Preliminary Payload Data Collection & Analysis
  - Utilization Tools
  - Payload Data Inputs
  - Payload-unique IA
  - GRC/MSD ISS Utilization Traffic Model Analysis
- Payload Major Milestones
  - Requirements Definition Review (RDR) at L-48 months
  - Preliminary Design Review (PDR) at L-36 months
  - Critical Design Review (CDR) at L-24 months
  - Verification & Test Review (V&TR) at L-18 months
  - Pre-Ship Review (PSR) at L-6 months

Planning	Launch Minus 4 Years						Launch Minus 3 Years						Launch Minus 2 Years						Launch Minus 1 Year					
	48	46	44	42	40	38	36	34	32	30	28	26	24	22	20	18	16	14	12	10	8	6	4	2
Major Milestones	◊ **RDR**						◊ **PDR**						◊ **CDR**			◊ **V&TR**						◊ **PSR**		
Payload Kick-Off Meeting	◊																							
IA Main Volume							◊ Preliminary						◊ Baseline											

FIGURE 13 PAYLOAD PLANNING ACTIVITY TIMELINE (TYPICAL)

5.1 Payload Kick-Off Meeting

Once a PD has successfully passed its Science Concept Review (SCR), the FCF Utilization Team schedules the Payload Kick-Off Meeting to familiarize the PD with the integration process. This meeting is typically held at L- 48 months at PD request. At this meeting, the FCF Utilization Team provides an overview presentation of the payload integration processes defined within this document and a schedule identifying the major milestone deliverables that the PD must meet. The schedule includes activities related to preliminary planning, multi-increment planning (planning for more than one increment), increment planning (one increment at a time), and integration management milestones. In addition to the schedule, overview documents and document templates are provided to assist the PD in meeting these integration milestones. This one-time meeting serves to help the FCF Utilization Team understand the unique needs of the new payload.

To assist the PD with the identification and management of FCF and ISS Program requirements, the FCF Utilization Team provides documents and document templates, as part of the Mission Integration process, for the unique requirements of the PD. The PD can use these documents and document templates during the initial conceptual phase of payload development prior to the actual payload-unique documentation development. Documents and document templates to be provided include:

- FCF-IA-MV-BB and FCF-IA-DS-BB
- FCF-IDD-CIR and FCF-IDD-FIR
- FCF-GPVP-CIR and FCF-GPVP-FIR
- FCF-PAH-CIR and FCF-PAH-FIR

The FCF Utilization Team provides access to GRC and ISS Program requirements and capabilities documents to aid the PD in the development of payloads. The following requirements and capabilities documents are specifically applicable for payload development:

- Standard Assurance Requirements and Guidelines for Experiments (GRC-M0510.002)

- Pressurized Payloads Interface Requirements Document (IRD) (SSP 57000)
- Payload Safety Requirements for On-Orbit Operations
    - Safety Policy and Requirements for Payloads Using the International Space Station (NSTS 1700.7B)
    - Safety Policy and Requirements for Payloads Using the International Space Station – ISS Addendum (NSTS 1700.7B ISS Addendum)
    - Payload Safety Review and Data Submittal Requirements (NSTS/ISS 13830)
    - Interpretation of NSTS/ISS Payload Safety requirements (NSTS/ISS 18798)
- Space Shuttle Payload Ground Safety Handbook (KHB 1700.7)
- ISS Pressurized Payload Accommodations Handbook (SSP 57020)
- Launch Site Accommodations Handbook for Payloads (K-STSM-14.1-REVI-LSAH)

5.2 Preliminary Payload Data Collection and Analysis

The payload data collection process involves assisting the PD in web-based entry of data and performing various analyses that focus on comparing resource requirements (i.e., ascent/descent mass and volume, crew time, power, on-orbit stowage, data downlink, etc.) for a given payload against available FCF resources. Payload data is submitted to the ISSPO, which works to secure the resources required. All FCF payloads follow this process.

5.2.1 Utilization Tools

Immediately following the kick-off meeting and subsequently at major reviews or significant design changes, the PD submits preliminary payload information to the payload data collection system via the MSD Payload Integration Website (https://node135.mrdoc.cc). Once data is submitted, the FCF Utilization Team reviews the data for consistency, uses it for analysis, and maintains it under configuration control.

5.2.2 Payload Data Inputs

The GRC MSD interfaces directly with the ISS Research Planning Working Group (RPWG). The RPWG develops integrated transportation models, integrated accommodations (interface) requirements, and integrated on-orbit operations models.

Data collected includes the following:

- Administrative – Payload name, acronym, ISS sponsor/developer
- Operations – Typical run time, crew time per run, on-orbit placement
- Hardware - Container type, location, mass, volume, late access, early access
- Power and Energy - Typical, peak, minimum continuous powers and durations, up/down transportation power
- Data and Video - Typical and peak downlink/uplink and durations, ISS video, High Rate Data Link (HRDL), 1553 data, Ethernet
- Fluids - Nitrogen, vacuum vent and vacuum resource Thermal – Heat rejection requirements (air and liquid)
- Logistics – Re-supply and return (R&R) mass and volume per run
- On-orbit Stowage - Passive, waste, and other volumes per run
- Microgravity – Active/Passive Rack Isolation System (ARIS/PaRIS), disturbance sources
- Transportation – Stage, flight, runs per stage, transportation location, on-orbit location
- Crew Training – Time required and definition of personnel

Multi-Increment and Increment data for multiple payloads is exported from the payload data collection system and submitted to the ISSPO electronically. The inputs contain all data for the three planning periods identified in the latest version of the Operations Summary, SSP 50112, and are revised annually and submitted to the ISSPO beginning at PP-54, PP-42 and PP-30 months. This data is used for long-term feasibility assessments and trade studies in support of long range planning.

5.2.3 FCF Payload-Unique Integration Documentation

The FCF Utilization Team uses the preliminary payload data collection and analysis processes to produce the IA MV, which includes the Utilization Schedule. The IA creation process is depicted in FIGURE 14.

5.2.3.1 Integration Agreement Main Volume

The IA MV describes the static requirements and the general roles and responsibilities of the parties involved in the integration/de-integration, prelaunch/post-landing processing, transportation, and the on-orbit operation of the payload. More specifically, it contains information pertaining to reviews, schedules, hardware commitments, and protocols required to manifest the payload. The IA MV preliminary submit is typically at the payload PDR with a baseline submit at the payload CDR and is finalized by I-22 months.

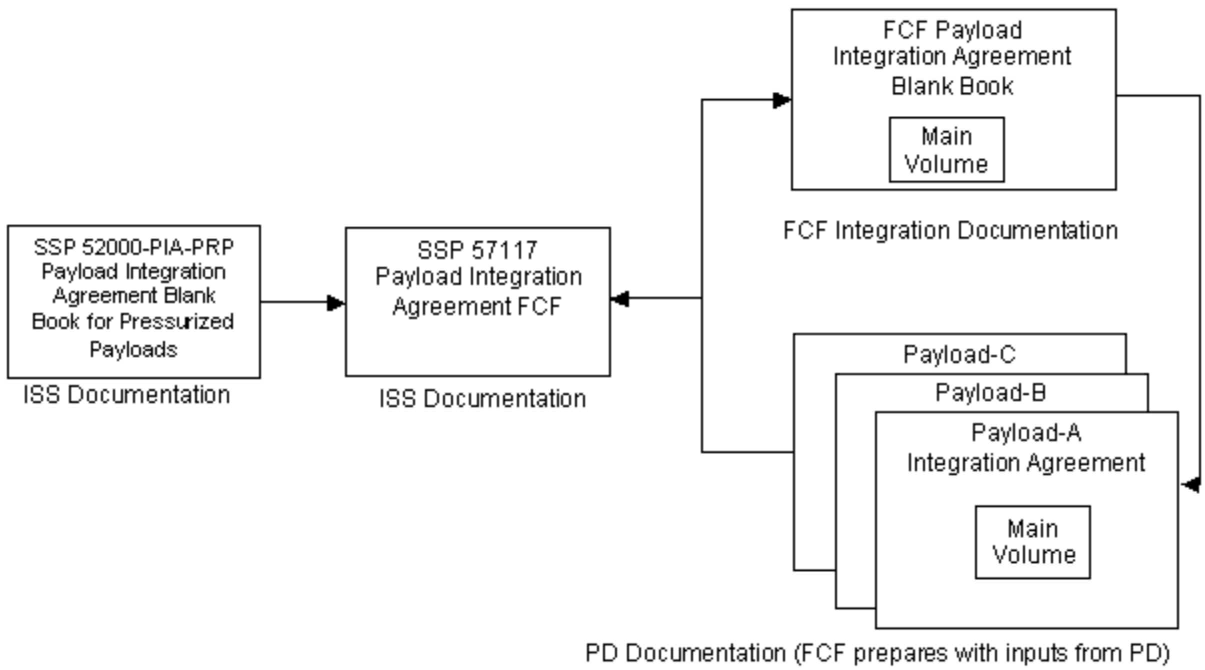


FIGURE 14 INTEGRATION AGREEMENTS

The Increment Schedule contains the actual dates for integration and operations products required for FCF Utilization. Specific review dates and schedules are defined for the use of FCF facilities such as simulators, EDU, or GIU used for payload development or integrated testing.

5.2.3.2 External PIRNs/CRs/Exceptions

The Planning Team is responsible for processing external ISS PIRNs, CRs, and Exceptions. A PIRN is written when a configuration managed document is changed, and the change could potentially affect other documents. A CR is similar to a PIRN, but offers the ability to provide input on the change before it is made. The need for an Exception is identified when a contractual requirement cannot be met.

5.3 GRC/MSD ISS Utilization Traffic Model Analysis

The GRC/MSD ISS Utilization Traffic Model is a summary diagram that identifies the launch and return flights for all payloads managed or sponsored by GRC/MSD. This Traffic Model (with the payload requirements) is continually validated against projected ISS resource allocations (ascent/descent volume, ascent/descent mass, crew-time, on-orbit stowage, downlink, power, etc.).

6.0 MISSION INTEGRATION

Mission Integration is the process by which the FCF Utilization Team coordinates the integrated FCF increment-specific activities and deliverables through an Increment Management function. Mission Integration acts as an advocate for the PD and coordinates internally across the entire FCF Utilization organization including Planning, Engineering, and Operations, and externally with the ISS Program. Payload-unique data for a particular increment is coordinated, combined, analyzed, and stored within the payload data collection system and maintained by the Mission Integration function. Agreements between the payload and FCF are established through the development of payload-specific documentation that defines the unique interface and verification requirements. Shuttle, ISS, and GRC reviews; including the Increment Requirements Review and Increment Acceptance Review, are conducted within this Mission Integration process.

The primary activities and/or products of the Mission Integration process are shown in FIGURE 15.

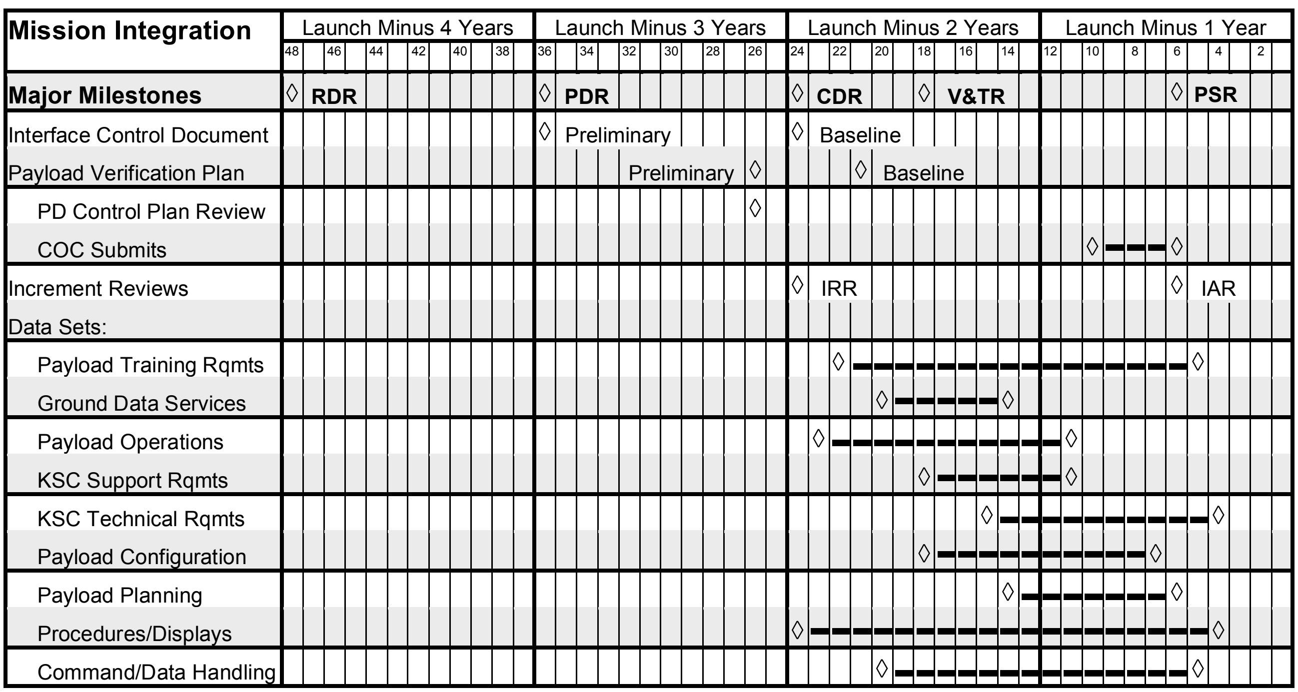


FIGURE 15 MISSION INTEGRATION ACTIVITY TIMELINE (TYPICAL)

6.1 Integration Documentation

For each ISS Increment, the FCF Utilization Team, within the Mission Integration function is responsible for aiding the development of payload-specific documentation. This documentation includes the ICD, PVP and maintenance of the Payload Integration Agreement (PIA) and payload-unique IA. These payload-unique documents are used to develop an integrated FCF submittal to the ISS Program that includes all payloads and FCF requirements for a given increment.

6.1.1 Integration Agreement Data Sets

The FCF Utilization Team uses the individual payload-unique Data Set inputs for particular increments along with FCF requirements to create a PIA Data Set for a particular ISS increment.

A Data Set defines, on an increment and flight-specific basis, the required engineering, integration, and operational details for a specific domain. The Data Set is updated, as agreed-to by the implementing organizations, to meet increment and flight-specific needs. In general, the Data Set contains additional details beyond what is provided by the PD for the payload data inputs.

The Payload Data Library (PDL) is a central repository for the payload data and is maintained by the ISS Program. For each ISS Increment, the FCF Utilization Team is responsible for consolidating FCF-specific and payload-unique data into a single electronic submittal to the ISS PDL (http://pdl.hosc.msfc.nasa.gov/) and the interim User Requirements Collection (iURC) web based tool (https://iurc.nexus.nasa.gov/) for each FCF rack and payload. The iURC data inputs, made on an increment and flight-specific basis, define the investigation operations, which include the procedures, power, thermal, and data resource requirements and investigation timeline information for flight planning purposes. The ISS database relationship is shown in FIGURE 16.

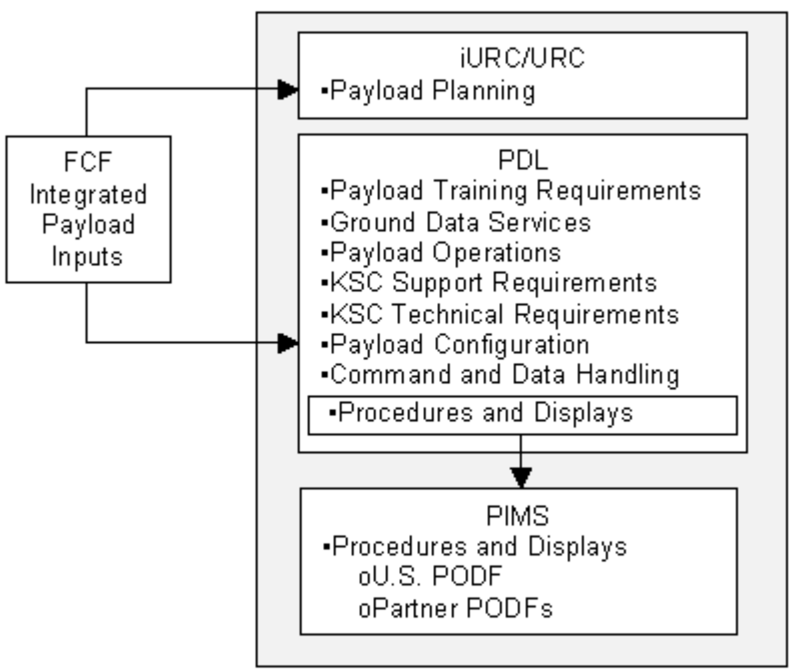


FIGURE 16 ISS PAYLOAD DATA SET DATABASES

Data Set Managers are assigned in appropriate areas, including Engineering and Operations, to gather, combine, and analyze the data and then provide it to Mission Integration for CM, approval, and final submittal. The PIA Data Sets are approved through the MSD Payload Integration Website routing system that requests authorization from appropriate individuals. The PIA Data Sets are then submitted to the appropriate ISSPOs per the ISS PIM schedule with FCF, as based on SSP 57057. These inputs are required 60 days ahead of the defined review dates. The PD either inputs required payload data directly into the Payload Database System, or the information is provided to an FCF-assigned Data Set Manager and documented through the payload-unique IA Data Set, as shown in FIGURE 17. Data Set Managers work with each Data Set to generate the integrated FCF (FCF plus payload) submittal for approval and submittal through the Mission Integration function. Both an FCF rack-level Data Set and a sub-rack payload Data Set are generated for each increment.

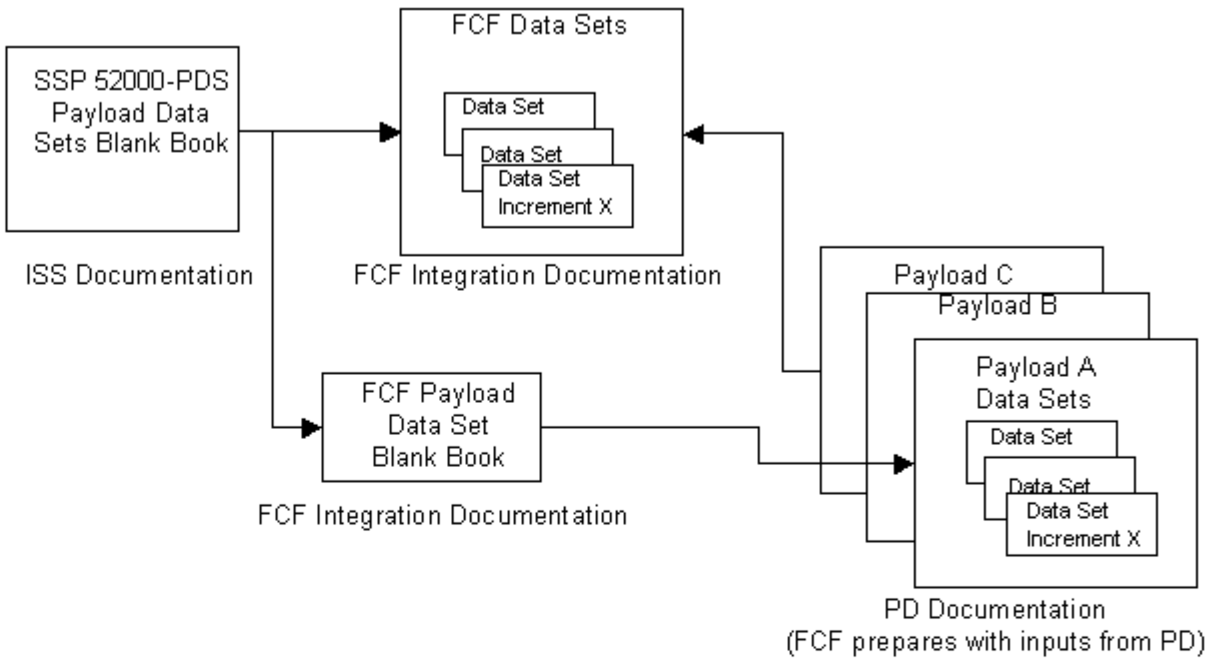


FIGURE 17 IA DATA SET

The PD generates the payload-unique Data Set inputs from a blank book template (FCF-IA-DS-BB) provided by the FCF Utilization Team. There are several submits of each Data Set as defined in the payload-unique Utilization Schedule. Post submittal, the ISS Program reviews and provides comments and then “baselines” the Data Set as noted below.

- Payload Training Requirements Data Set – Provides the detailed training requirements for the PD, the FCF Utilization Team, and the ISS Personnel, including flight crew and GSP. These are top-level training requirements, including the integrated training location, the complexity of training, the crew training hardware, and the supporting hardware and services. This Data Set is due at I-20 months (Submit) and baselined at I-18 months. GSP user inputs for training are due at I-9 months (Submit) and are finalized by I-3 months.

- Ground Data Services Data Set – Provides the detailed requirements that include the payload services required for PDs and scientists located in the TSC. The Data Set addresses PD identification and definition of voice loop requirements and real time data/video requirements, as well as payload telemetry requirements. The voice/data inputs are due at I-20 months (Submit) and are baselined by I-17.5 months. The Payload Operations and Integration Center (POIC) inputs are due at I-17 months (Submit). The User Support and Operations Center (USOC)/TSC inputs are required by I-17 months (Submit) are baselined at I-18 months.
- Payload Operations Data Set – Provides the detailed flight operations requirements for the PD and ISS personnel. There are several parts of this Data Set to be completed by the PD; including:
    - Operations Contact Information at I-23 months
    - Initial Video/Photo Requirements (Submit) at I-18 months
    - Launch Commit Criteria (LCC), Flight Rules, and Payload Regulations at I-12 months
    - Post-Payload Photo/Video deliverables, real-time operations/facilities/other payload operations, contacts, and real-time operations team structure at I-11 months.
- KSC Support Requirements Data Set – Documents the launch and landing site advanced planning for ground processing support requirements necessary to process a single ISS payload through the following activities: simulations, preflight, in-flight, and post flight phases with launch and recovery on the Space Shuttle System. This includes both hardware and science items to be processed at the launch and landing sites. The KSC Support Requirements Data Set draft is due at L-18 months (Submit), and at L-14 months (Preliminary Submit). This Data Set is baselined at L-11 months.
- KSC Technical Requirements Data Set – Details the payload operations and maintenance requirements that are to be levied on KSC. These technical requirements are those that KSC is to perform on a payload during pre-launch, launch, recovery, and turnaround operations.
    - ISS to Payload Operations and Maintenance Requirements Specification (OMRS) (Preliminary Submit) at L-14.5 months
    - ISS to Payload OMRS (Preliminary) at L-14.5 months
    - ISS to Payload OMRS (Baseline) at L-11 months
    - Orbiter Middeck Payload OMRS, File 2, Volume 2 (Preliminary Submit) at L-8 months
    - Orbiter Middeck Payload OMRS (Preliminary) at L-7 months
    - Orbiter Middeck to Payload – Time Critical Ground handling Requirements (TGHR) Table (Preliminary Submit) at L-6.5 months
    - Orbiter Middeck to Payload – TGHR Table (Preliminary) at L-6 months
    - Orbiter Middeck Payload OMRS (Baseline) at L-5 months
    - Orbiter Middeck to Payload – TGHR Table (Baseline) at L-4 months

- Payload Configuration Data Set – Details the Payload Engineering, Integration, and Configuration Requirements Data. This data comprises three main groups used by various teams within the ISS Program: (1) Payload Drawings, Schematics, Configuration Data, (2) Payload Models, and (3) Payload Manifest/Stowage Data. The Payload Configuration Data Set (Baseline Submit) is due at L-18 months. The Sub-kit Data Submit portion of this Data Set can be updated (Update Submit) one time at L-10 months, with the Payload Configuration Data Set final update required at L-5 months.
- Payload Planning Data Set – Provides the detailed pre-increment and real-time planning and payload resource requirements for the ISS Program. The data is used for modeling the PD's requirements for on-board activities. The Payload Planning Data Set (Baseline Submit) is at I-14 and is baselined at I-11.25 months. An update (Final Submit) is required at I-8 and is finalized by the ISS Program at I-6.25 months.
- Procedures and Displays Data Set – Provides the detailed requirements for ground and flight procedures and displays used by both ground personnel and the crew. There are many inputs required, as described below:
    - Operations Concept (Optional Submit) at L-36 months
    - Operations Analysis/Flows (Optional) at I-24 months
    - Initial Crew Displays; Payload-Unique Operations Nomenclature (Preliminary) at I-22 months
    - Engineering Drawings (ISS Payload Label Approved Team (IPLAT) Review) (Pre-Released) at I-20 months
    - Payload-Unique Operations Nomenclature/Engineering Change Request (ECR) (Update); Candidate Flight Crew Displays at I-19 months
    - Manual Procedures; Delivered Procedure/Display Files List at I-18
    - Reference Data; Validation Plan; Validation Record Report at I-18
    - Log Files; Manual Procedures Viewer (MPV) Links; Payload Messages at I-18 months
    - Ground Command Procedures (Preliminary) at I-11 months
    - Engineering Drawings (IPLAT Review) (Released) at I-10 months
    - Ground Command Procedures at L-8 months
    - ECR to Baseline Manual Procedures at I-7.5 months
    - Delivered Procedure/Display Files (Update) at I-7.5 months
    - Validation record Report (Update) at I-7.5 months
    - Log Files (Update); MPV Links (Update); Payload Messages (Update); Procedure Hazard Control List at I-7.5 months
    - Ground Command Procedures (Final) at I-6 months
    - Payload Data Files; Payload Automated Procedures (Timeliner Files) at L-2 months
- Command and Data Handling Data Set – Provides the requirements for commanding and data handling for telemetry returned to the ground. The Command and Data handling Data Set (Preliminary) inputs are required at L-20 months and are baselined at L-5 months if the program is to build (i.e. reflight); otherwise, they are required at L-11 months.

6.1.2 Payload-Unique Documents

From the IDD and GPVP, which are provided to the PD at the initial Payload Kick-Off Meeting, the FCF Utilization Team customizes each payload design document in coordination with the PD. The ICD and PVP are required at both the FCF to ISS and payload to FCF levels. This process is shown in FIGURE 18.

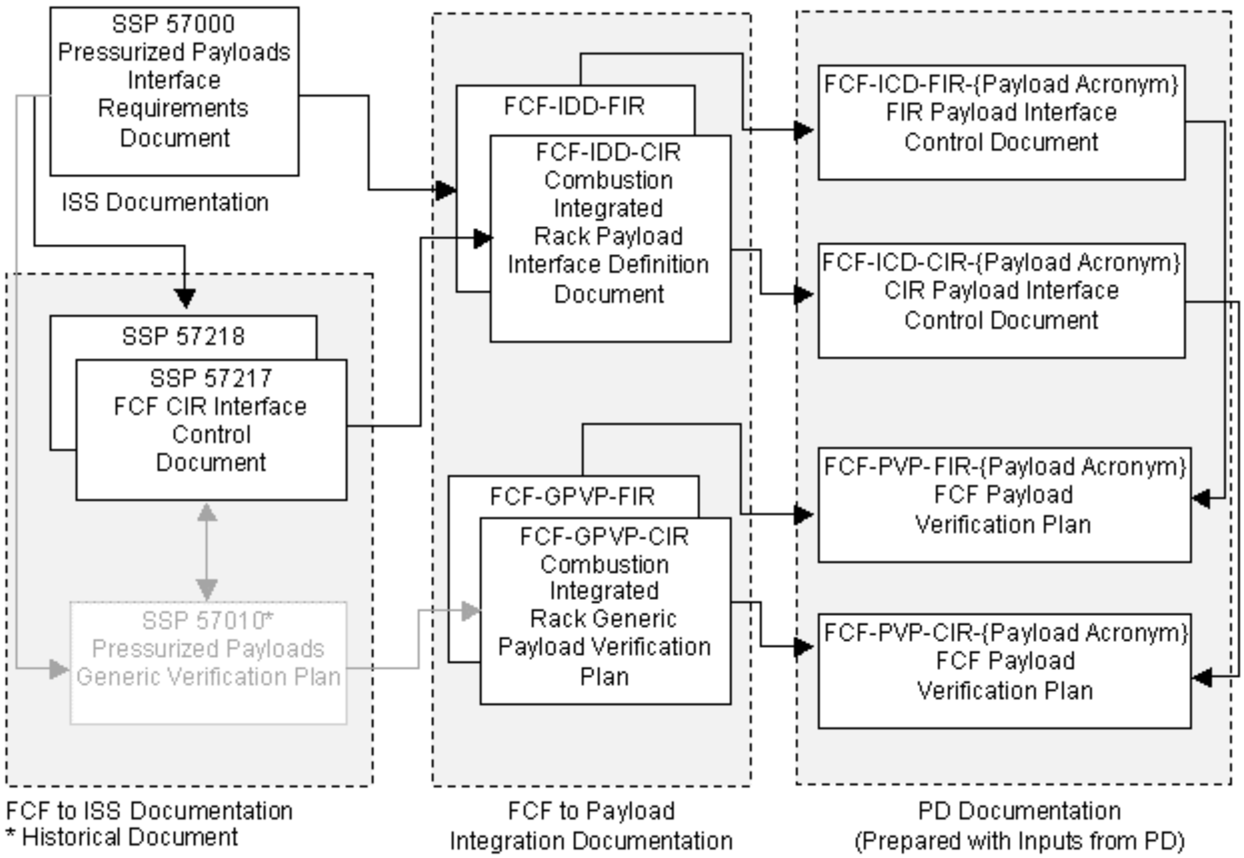


FIGURE 18 INTERFACE CONTROL AND VERIFICATION DOCUMENTS

6.1.2.1 Interface Control Document

The ICD defines and controls the generic and payload-unique interfaces with the FCF. The initial draft is based on the IDD developed for each FCF rack. Standard FCF provisions are selectively identified in accordance with requirements as previously agreed to in the payload-unique IA. A preliminary submit of the ICD is required 45 days prior to PDR, and the baseline submit is required 45 days prior to CDR. Final updates to the software portion of the ICD can be made as an update at L-15 months (Update 1) and L-9 months (Update 2).

6.1.2.2 Payload Verification Plan

An initial draft of the PVP is prepared and delivered to the PD by the FCF Utilization Team at the PDR at L-36 months (Preliminary Submit). The initial draft is based on the GPVP templates developed for each FCF rack. The PVP covers the verification process that is implemented to ensure that FCF requirements and ISS Program requirements are met. A preliminary version is prepared 45 days prior to CDR, and then baselined by L-19 months.

The core of the verification plan is a set of Verification Data Sheets (VDSs) that identify how each payload requirement is verified. Verification methods include inspection, demonstration, analysis and testing. Additionally, VDSs identify when the verifications must be completed in order to meet the launch and increment schedules. Generally, preliminary submittals are required to be submitted to the FCF Utilization Team at L-9.5, and then final at L-5.5.
In some cases the VDSs reference control plans that provide detailed verification plans and procedures required to verify critical requirements such as fracture control, acoustics, microgravity, and electro-magnetic interference (EMI). These control plans are typically required for review around the payload CDR at L-24 months. The VDSs identify any functional testing that is performed with FCF functional equivalent ground hardware.

The PD provides a Certificate of Compliance (COC) stating that all of the required verifications that can be done solely by PD have been performed. The FCF Utilization Team, after working with the PD to perform joint tests/demonstrations, combined analyses, or combined inspections, provides a COC stating that all of the required joint verifications have been performed. As the verifications are completed, all supporting data is gathered by the FCF Utilization Team for incorporation into an overall verification package, rack level verifications or re-verifications, joint PD/rack verifications, and unique PD verifications. This overall verification package is submitted to the ISS Program.

6.1.2.3 Internal PIRNs/CRs/Exceptions

Any PIRNs/CRs/Exceptions that are produced internally are the responsibility of the Mission Integration Team. A detailed breakdown of the tasks associated with these responsibilities is contained in the ISS Exception, PIRN, CR and FCF Exception Processes (MRD-PRC-0011B).

6.2 Increment Reviews

The Increment Requirements Review (IRR) and Increment Acceptance Review (IAR) are two GRC increment-specific reviews that are generally conducted prior to each ISS increment. For initial FCF combustion and fluids payloads (i.e., those payloads deployed to ISS when FCF racks are deployed) no IRR or IAR is held because of the close connection between the simultaneous development of both the rack and subrack.

6.2.1 Increment Requirements Review

The specific purpose of the IRR is to review and accept for implementation the new requirements coming from payloads operating in the subject increment, beyond those requirements already verified in earlier increments, which are being placed on the rack(s) or other external entities (ISS, TSC, POIC, etc.). These requirements could involve hardware implementation, software implementation, or operational implementation by the rack(s). Prior to the review the rack(s) must explore the implementation of these requirements (cost, schedule, feasibility). The IRR is scheduled between L-24 and L-18 months. The documents that are specifically evaluated for this review are limited to those affected by the new requirements. They may include:

- IA
- ICD
- PVP
- Engineering Compliance Matrix
- Safety Data Packages
- Training Plan
- On-orbit installation and checkout plan
- Any nominal planning for FCF replacement/upgrade hardware or software

6.2.2 Increment Acceptance Review

The specific purpose of the IAR is to review and accept the rack-level and/or external entity implementations of the new PD requirements for the subject increment. The IAR is conducted at L-6 months. The documents that are specifically evaluated for this review are limited to those affected by the new requirements. They may include:

- IA
- ICD
- PVP
- Engineering Compliance Matrix
- Safety Data Packages
- Training Plan
- On-orbit installation and checkout plan
- Any nominal planning for FCF replacement/upgrade hardware or software
- Payload and Rack Verification tracking logs
- IRR Request for Action (RFA) Closeout

7.0 ENGINEERING

The Engineering Team performs integration and sustaining engineering functions. Its members work with the PD to integrate the payload into the FCF through integration and interface verification of hardware and software. The Engineering Team supports the PD with FCF interface verification and integration, assists the PD with FCF integration and checkout; including ground processing (analytical and physical integration), performs KSC ground processing as required, performs trend analysis and data archiving for FCF test facilities, trains the FCF GSP on all ground procedures, and performs sustaining engineering. The PD has joint responsibility with the FCF for safety compliance with ISS and National Space Transportation System (NSTS) flight and ground processing requirements. The FCF Utilization Team assists the PD with familiarization and integration into the Safety Review process.

The Sustaining Engineering Team's responsibilities include FCF maintenance, repair, reconfiguration, logistics, and new hardware and software development for all ground infrastructure hardware and software. The Sustaining Engineering Team maintains and provides the facilities, including the EDU, the GIU, and any simulators, to the PD for hardware, software, and procedure development and verification.

7.1 Engineering Integration

The Engineering Integration process focuses on the performance of analytical and physical integration, verification and checkout of the payload before shipping the payload to the launch site for integration into the launch vehicle, delivery of the payload to the launch site, and the return of the payload and data to the user post-flight. The primary activities and/or products of the Engineering Integration process are summarized below and shown graphically in FIGURE 19.

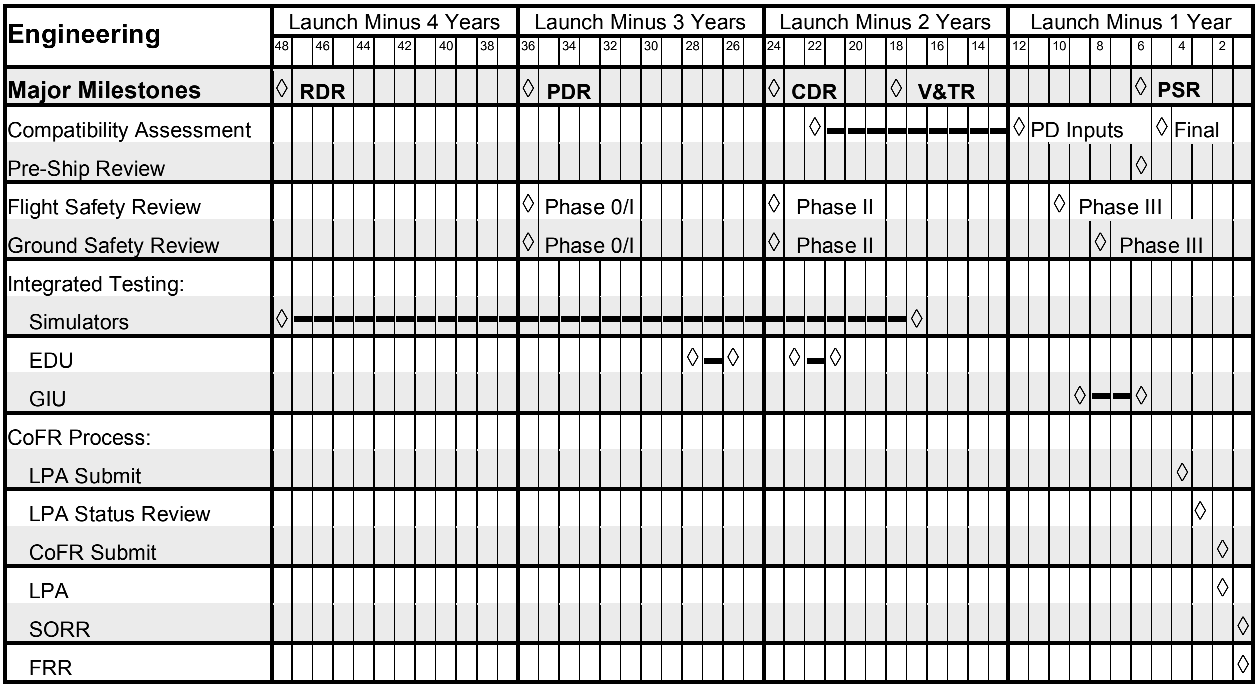


FIGURE 19 ENGINEERING INTEGRATION ACTIVITY TIMELINE (TYPICAL)

7.1.1 FCF Payload Compatibility Assessment

FCF payload design compatibility assessments are conducted by the FCF Utilization Team under the Engineering function to determine compliance with design, operational, and interface requirements, and result in the resolution of any incompatibilities between the FCF and the payload. The FCF Utilization Team will perform assessments for the following:

- Structural/Mechanical/Mass/Microgravity Properties – A review of the integrated FCF; including payload mass and center of gravity, modal analysis or test, stress analysis data, and microgravity environment analysis, are performed to evaluate compatibility with FCF structural interface and mass/Center of Gravity (CG) capabilities. Fracture control data is required. The payload data is analyzed to verify that defined envelopes are not exceeded.
- Active/Passive Thermal and Environmental Control – A review is performed to verify compatibility of the experiment’s thermal and environmental interfaces and requirements with the integrated FCF thermal interface capability.
- Power/Energy – Experiment power and energy requirements are evaluated for compatibility with the integrated FCF allocations, and inputs to timeline activities are provided to manage integrated increment power and energy usage. The definition of all electrical interfaces, cable harnesses, required FCF hardware, and Payload experiment hardware is performed to assess for compatibility with mission planning and operations. Interface and system test requirements are defined and evaluated.

- EMI/EMC – Individual experiment tests and analysis data is reviewed for component and integrated FCF system compatibility with FCF and ISS Program requirements.
- FCF Hardware Interface Requirements – Physical interfaces, including audio, video, vacuum system, pressurized gas, and fire protection, are verified for compatibility with FCF components.
- Command and Data – Each experiment is assessed for compatibility with the FCF capabilities and any unique services that FCF may provide. The adherence to standard formats, timing, isolation, signal levels, and other data system requirements are reviewed for the integrated FCF configuration. Interface and system test requirements are defined and evaluated.
- Materials and Processes – Material Identification and Usage Lists (MIULs), Materials Usage Agreements (MUAs), and test data and safety hazard closures for flammability, toxicity, and stress corrosion are reviewed to ensure the compatibility of the individual experiments with FCF and ISS.
- Human Factors – Experiment interfaces are reviewed to ensure that they are compatible with FCF hardware, in-flight installation, and maintenance and deinstallation plans, and that experiment flight elements do not expose the crew to protrusions, rough surfaces, sharp edges, pinch points, finger traps, touch temperatures, and/or any other hazards. Acoustic requirements must be met to ensure crew safety.
- Software – Assess that the PD integrated software is fully compatible with the FCF system software.

Verification tests and analysis inputs to the FCF Utilization Team are typically required by L-12 months, with these exceptions: stress analysis with an initial input at L-22 months, final analysis by L-5 months, and a natural frequency model required by L-19 months. Verification Data Certifications are typically required by L-20 months for gas/contaminant type inputs, and between L-6 and L-12 months for all other data certifications.

7.1.2 Ground Processing

Ground processing for payloads begins when a PD requests the use of simulators from the Engineering Team, continues with the subsequent delivery of simulators, and ends with the handover of a payload to the launch site for stowage.

For each FCF rack on-orbit, there are two supporting racks on Earth. There are also simulators available to a PD for early breadboard/hardware/software development. A rough timeline for typical payload usage of the Ground Segment is shown in FIGURE 19. FCF ground racks and simulator hardware are supplemented with a variety of other GSE to facilitate development and final verification of payloads for flight in the FCF. The FCF ground processing concept for payloads, as shown in FIGURE 20, provides the infrastructure for payload ground processing and is comprised of the following elements:

- Simulators for payload development

- o EDU for payload development
- o GIU for payload verification
- o Ground Handling and Testing Equipment

FIGURE 20 FCF GROUND PROCESSING FOR PAYLOADS

7.1.2.1 <u>FCF Simulators</u>

The Engineering Team provides component simulators to the PD (most simulators can be delivered to the PD site) to assist a payload in hardware development during conceptual and final design phases (typically between L-48 and L-18 months). Simulator hardware is designed to emulate interfaces between FCF and the payload. Simulators for CIR, FIR, and other hardware simulate electrical and Command & Data Handling (C&DH) interfaces (i.e., Input/Output Package (IOP), Fluid Science Avionics Package (FSAP), Image Processing and Storage Unit (IPSU), Diagnostics Control Module (DCM), and Electrical Power Control Unit (EPCU)). These simulators are used extensively for preliminary interface verification testing between the payload and FCF. The FCF provides configurable hardware simulators of FCF-provided diagnostics that may be used by PDs (i.e., FCF cameras, light sources, etc.). Specific plans for the use of simulators during payload ground processing activities are defined in the FCF Ground Processing Plan, FCF-PLN-0031.

PDs request the use of simulators per the instructions in the Ground Processing Management Plan (FCF-PLN-0655). Simulator availability is dependent on the number of PDs supported over a given 48-month period, and therefore is a negotiated resource with FCF. Component simulators are tracked by the FCF Utilization Team as part of the logistics function under Sustaining Engineering. Each simulator is functionally tested before it is turned over to a PD for use. Along with the simulator, the PD receives a user's guide and logbook to track use and performance of the simulator. When returned, the simulator is re-tested and returned to the FCF inventory.

7.1.2.2 FCF Engineering Development Units

EDUs, located in Building 333 at GRC, are flight-like FCF units (i.e., high fidelity models that are very similar though not identical to the flight unit). An EDU allows a payload access to FCF-like interfaces, and several tests are typically conducted between L-28 and L-20 months, as shown in FIGURE 19.

The EDU is typically used for initial interface verification and configuration selection testing. Payload engineering hardware is integrated into the FCF rack EDU to support interface functional verification (mechanical, electrical, thermal, software and fluid), preliminary science acquisition, preliminary FCF configuration and parameter selection, test sequence identification, and crew procedure validation. This testing nominally occurs between the payload PDR and CDR. Payload hardware can be integrated into the EDU to support preliminary interface verification, ground science acquisition, FCF configuration and parameter selection, test sequence identification, and PD familiarization training. This testing occurs prior to payload flight unit testing with the FCF GIU.

Each EDU has an operator's manual, procedures for maintenance, and a logbook for tracking configurations, use, anomalies, etc. Logbook information is entered into a database for metrics tracking. Test plans and test reports are generated that document the purpose of the testing, the configuration of the hardware, and the results. All science data generated is delivered to the PD and all hardware and software engineering data is archived in the FCF CDS.

7.1.2.3 FCF Ground Integration Units

Pds are required, at a minimum, to perform final interface verifications with the GIU prior to shipment to the launch site. GIUs for the CIR and FIR are located at GRC in Building 333 and are used for final interface verification testing (FIVT) of payload hardware and software, as well as for simulating or troubleshooting on-orbit operations. The GIUs are identical to the Flight Unit, with the exception that the GIUs do not include functional ARIS/PaRIS hardware. The configuration of the GIU is carefully controlled so that it can be used for both simulating on-orbit operations and FIVT of payload hardware and facility upgrade hardware prior to their launch to ISS.

This final interface and verification testing typically occurs between L-9 and L-6 months. The hardware and software configuration is frozen at the successful conclusion of the

FIVT. If any changes in hardware or software (FCF or payload) are required after the FIVT, the FIVT must be repeated. For initial FCF combustion and fluids payloads (i.e., those payloads deployed to ISS when FCF racks are deployed), FIVT occurs via installation and test of payload flight hardware in the FCF flight units before their launch. After that, all ISS/FCF and payload flight hardware is integrated into the GIU and tested in it prior to launch. Testing in the GIU includes high-fidelity interface verification and an abbreviated mission simulation to fully exercise the hardware and software interfaces. Test plans and reports are generated each time the GIU is used in order to document the purpose of the testing, the configuration of the hardware, and the results. All science data generated is delivered to the PD and all hardware and software data is archived in the CDS. Once verification in the GIU is complete, the PI hardware is shipped to the launch site for off-line and on-line processing.

The GIUs are resources controlled by the FCF Utilization Team. Training is required to use the GIUs. Each GIU has an operator's manual, procedures for maintenance, and a logbook for tracking configurations, use, anomalies, etc. Logbook information is entered into a database for metrics tracking.

7.1.2.4 FCF Training Units

FCF Training Units are deployed at the JSC to support crew training. Early crew training concentrates on rack assembly and checkout. The FCF Training Units are not powered for crew training, but crew display interface training simulates a powered rack. Crew display training simulates flight-like feedback for the crew and enables the ability to recognize nomenclature and graphics. Integrated FCF Training provides crew experience with reach constraints, experience in manipulating stowage hardware, and familiarity with the overall payload operations. The integrated FCF training addresses nominal operations, maintenance, and malfunction scenarios.

The Training Units may be supplemented with part-task trainers, as necessary, to train the crew on the installation, operation, and maintenance of payload-unique hardware or specialized FCF hardware. Part-task trainers could consist of rack subsystems (e.g., facility-provided diagnostics) or other hardware components that require more focused, intensive training by the crew. The FCF Utilization Team maintains a list of hardware located with the Training Units. This hardware is used for the maintenance and support of the units.

7.1.2.5 FCF Mockups

Mock-ups of the FCF racks (CIR and FIR) have been constructed to provide a visual representation and limited mechanical functionality that can demonstrate the FCF (i.e., optics bench tilt, camera and diagnostics change-out, basic functional capability) for public relations and advocacy activities. These FCF rack mock-ups may be installed in a mock-up of the U.S. Laboratory Module and transported to various meetings, conferences, symposiums and outreach events for exhibition. At other times, these mock-ups are nominally located in Building 110 at GRC. PDs may want access to this hardware early in their development phase to assist in conceptual designs.

7.1.2.6 FCF Ground Support Equipment

GSE falls into two categories: ISS simulators and FCF-unique GSE. A description of the major units available for integrated FCF testing follows.

7.1.2.6.1 ISS Simulators

A Payload Rack Checkout Unit (PRCU) is used for final verification and acceptance testing of the flight units (FCF and initial fluids/combustion payloads). Additionally, the PRCU is used to emulate ISS interfaces for operation of the FCF GIUs. A PRCU supplied to the FCF by the ISS Program is located in Building 333 at GRC. This unit is capable of simulating all interfaces from ISS to the FCF racks, such as the power supply, C&DH system, Vacuum Resource System (VRS), Vacuum Exhaust System (VES), Moderate Temperature Loop (MTL) cooling water, and the Nitrogen (N_2) gas supply.

A Suitcase Test Environment for Payloads (STEP) may be used to emulate ISS data interfaces for operation of the FCF EDUs and/or GIUs. This is done to support payload integration and payload ground processing. The STEP is supplied to FCF by ISS and simulates the ISS C&DH system to the FCF, including the ISS payload MDM and the Payload Ethernet Hub/Gateway (PEHG).

7.1.2.6.2 FCF-Unique Ground Support Equipment

The following FCF-unique GSE is used to support ground processing in Building 333 at GRC.

The Ground Rack Handling Adaptor (RHA) provides structural support for the ISPR and lifting capability by forklift via the base.

The Gaseous Nitrogen (GN2)/Vacuum Resource Test Cart is used to control, monitor, and provide GN2 and vacuum resources to the EDUs during integration and ground segment operations.

The Optics Bench Rotation Device (OBRD) is designed to operate safely and continuously with the rack doors open and the optics bench rotated to any angle ±2.5°, within the 90° range of motion of the optics bench, from the nominal vertical to the fully deployed horizontal. The OBRD supports EDU, GIU and flight operations.

The 9kW Water Chiller is used to control and provide cooling resources to the EDUs during integration, test and PD operations.

The Power Supply Test Equipment Rack simulates the ISS power resource to the EDUs during integration, test, and operations.

7.1.3 FCF Payload Integrated Testing

The FCF Utilization Team is responsible for ground processing facilities located in Building 333 at GRC through the development and maintenance of a Ground Processing Management Plan (FCF-PLN-0655) that includes controls for the facility working environment, facility security, safety, bonded storage capabilities, facility layout, use of FCF EDUs, GIUs, and simulators, payload processing schedule, and any required tag-up meetings. A process for initiating and implementing integrated payload and FCF testing is provided in Appendix C of this document.

7.1.4 Safety Reviews

The PD is responsible for compliance with ISS/NSTS flight and ground safety requirements. The FCF Utilization Team assists the PD with familiarization and integration into the Safety Review process, as shown in FIGURE 21.

The FCF Utilization Team and the PD determine hazard control jointly. The PD prepares the Safety Data Package (SDP) containing safety analysis and hazard identification for Phase 0/I, Phase II, and inputs to Phase III Safety Reviews. The PD interfaces directly with the JSC for the flight safety reviews and with the KSC for the ground safety reviews, for both Phase 0/I and Phase II, with the FCF Utilization Team in a support role. Any payload-unique hazards are identified by the PD and included in the SDP. The Phase III safety reviews are presented by the FCF Utilization Team and include both the FCF and payload complement, with the PD in a support role. The Payload Phase 0/I Flight Safety Review is typically performed at PDR +/- 2 months, Phase II at CDR +/- 2 months, and the FCF Phase III (including payload complement) Flight Safety Review is typically performed by L-9.5 months. The Payload Phase 0/I Ground Safety Review is typically performed at PDR +/- 3 months, Phase II at CDR +/- 2 months, and the FCF Phase III (including payload complement) Ground Safety Review is typically performed by L-7.5 months.

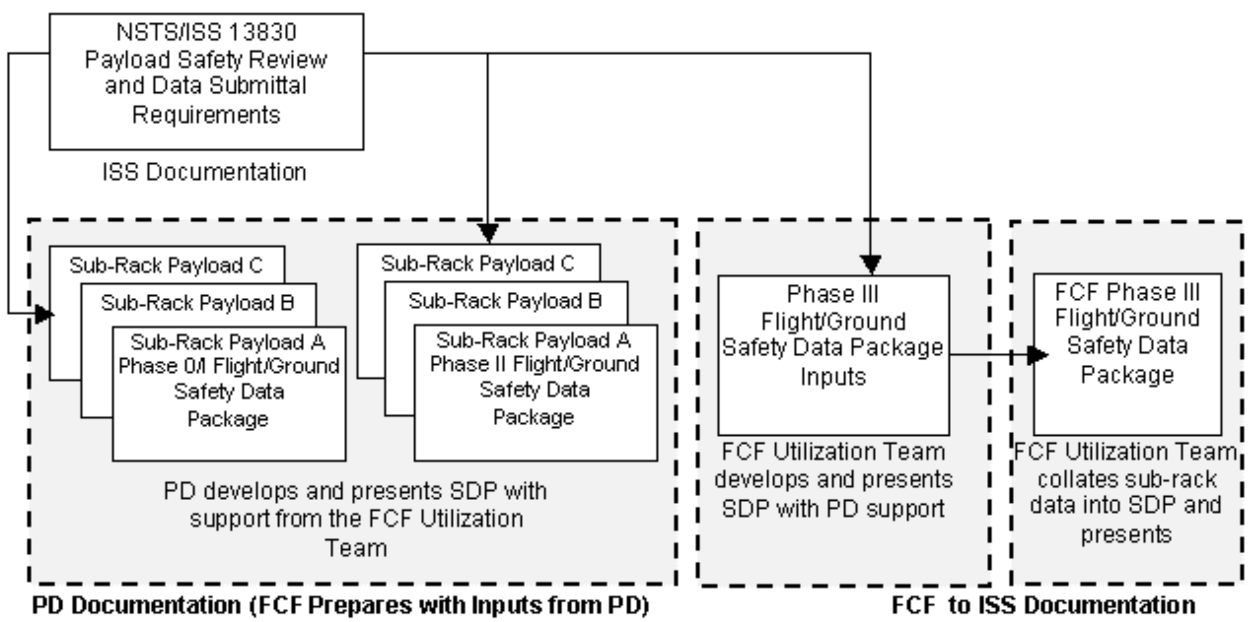


FIGURE 21 FCF AND PAYLOAD DEVELOPER SAFETY DOCUMENTS

7.1.5 Pre-Ship Review

A PSR is conducted at L-6 months prior to shipment of the payload to the launch site for launch vehicle integration. The overall purpose of the review is to obtain approval from GRC management that the flight experiment meets all requirements and is ready to be shipped. A detailed explanation of PSR activities is contained in the Directorate Work Instruction Pre-Ship Review (PSR) (GRC-W6000.001).

7.1.6 Certification of Flight Readiness

The Certification of Flight Readiness (CoFR) process focuses on the readiness of a payload at time of launch and crew-related readiness at the beginning of an increment, as defined in the ISS Program Payloads Certification of Flight Readiness Implementation Plan, Generic (SSP 52054). The endorsement statements address readiness of payload hardware/software to be launched for its intended mission, on-orbit readiness to receive the launch items, including lifetime and cycle limits for all payloads to be operated, and readiness for integrated payload operations.
The FCF CoFR process begins with the Launch Package Assessment (LPA). The LPA provides the status of an organization's readiness to support launch and mission operations. The PD provides inputs to the FCF Utilization Team at L-15 weeks. These inputs consist of an Open Work Tracking Log (SSP 52054 Table 6.2-1) that identifies all open work required to complete the CoFR endorsements, including constraints, risks, and completion dates, a list of previously approved exceptions and waivers, and a statement of readiness for payload transfer to the pad. The FCF Utilization Team integrates the LPA inputs and develops an LPA letter for MSD Chief signature at L-13 weeks. The LPA letter and integrated inputs are provided to the ISS Program at L-12 weeks. The ISS Payload Mission Integration Team (PMIT) conducts an LPA Status Review at L-10 weeks and the ISS Program Manager conducts the actual LPA at L-7 weeks.

The CoFR process continues with the submittal of readiness certification statements to support the CoFR for each flight. For each flight, certification statements are provided for payload design and as-built hardware, safety, crew and ground readiness, operations products, mission planning, and payload return. At the first flight of an increment, certification statements are provided for crew and ground team operational readiness for the entire increment. For payload hardware/software to be launched in support of a payload already on-orbit, certification statements are provided to address the on-orbit readiness to receive/support the payload hardware/software and the new on-orbit configuration. Certification statements are also provided if the on-orbit payload hardware/software configuration has been modified since the last CoFR, or the on-orbit time limit for the payload has expired. The replacement of a sample is not considered a configuration change. For payloads being returned, certification statements are provided that unique payload procedures for return and ground handling reflect disposition of any in-flight anomalies and that the payload is compatible with the return vehicle environment.

The PD submits specific CoFR inputs to the FCF Utilization Team at L-9 weeks. These inputs consist of an Endorsement Checklist (SSP 52054 Tables E-1 and E-2), an updated Open Work Tracking Log (SSP 52054 Table 6.2-1) that identifies all open work required to complete the CoFR endorsements, including constraints, risks, and completion dates, a list of previously approved exceptions and waivers, and an endorsement statement for launch and mission operations. The FCF Utilization Team integrates the CoFR inputs and develops the CoFR Endorsement Recommendation Letter for GRC MSD Chief signature at L-7 weeks. The CoFR Endorsement Recommendation Letter and integrated inputs are provided to the ISS Program at L-6 weeks. The ISS Program Manager conducts the Stage Operations Readiness Review (SORR) at L-3.5 weeks. The CoFR process culminates with the Joint Shuttle/ISS Flight Readiness Reviews (FRR) conducted at L-2 weeks.

7.1.7 Ground Operations

Ground operations encompasses the launch and landing site processing that covers the time periods between the receipt of the payload at the launch site, to the launch of the flight hardware; and from the landing of the flight, through de-integration and return of hardware to the PD. The PD develops and implements launch site operations and test procedures for the payload hardware, supports the development of the requirements for testing, servicing, and facility services required to process the payload hardware through carrier integration and pre-launch activities, monitors tests, evaluates test data, maintains records problems, and ensures the payload hardware has been properly tested at the launch site. Payload sample loading may be required at the launch site.

7.1.7.1 Launch Site Processing

After successfully completing the PSR, the FCF flight hardware is shipped to the launch site. This occurs at approximately L- 6 months. The PD coordinates with the FCF Utilization Team for all cleaning, fluid charging, packaging, documentation and transportation of the payload to the launch site. This includes the preparation of detailed packing lists identifying all components being shipped. Prior to packaging each item, a visual inspection is performed to identify the state of the hardware prior to transportation. In addition, all elements are weighed to obtain a final as-shipped weight summary.

Launch site testing for payload hardware is limited to off-line laboratories (i.e. no FCF rack simulators are available at the launch site). This may include post shipment inspection and limited power on testing. The PD is responsible for working with launch site personnel to add/modify requirements, concur on procedures, analyze data, and make engineering recommendations and decisions required by any conditions not within specifications. After off-line processing is complete, the hardware is turned over to the launch site for packaging and bench review prior to installation into the carrier transport system.

7.1.7.1.1 FCF Offline Lab Processing

Post shipment inspections and health checks are performed offline by the PD. In order to ascertain whether any damage occurred during shipment, limited functional testing of flight units may be performed utilizing the Payload Rack Checkout Unit at KSC. This testing is expected to take 1 to 2 weeks. These tests are limited to tests that do not invalidate final verifications of flight hardware that were previously performed. Once this testing is complete, all flight hardware is turned over to KSC at approximately L-5 months (except for any items that may require late processing) with required acceptance data.

Processing of all FCF and payload flight hardware at KSC follows the guidelines and requirements in SSP 52000-PAH-KSC and KHB 1700.7. FCF payload processing at KSC is defined in the KSC Support Requirements Data Set.

7.1.7.1.2 Space Station Processing Facility Intermediate Bay and High Bay Processing

If the payload is accompanied by a GIU, testing can occur using the Payload Test Checkout Stand (PTCS) to check ISS-FCF interfaces prior to launch. These tests should not invalidate previous FCF verifications conducted. Hardware that is to be launched in stowage must be removed after Space Station Processing Facility (SSPF) intermediate bay processing and before carrier integration. Measurements of FCF rack weight and center of gravity and installation of FCF flight racks into the carrier transport system are performed during high bay processing.

7.1.7.1.3 Launch Delay/Scrub Turnaround Processing

Delays in launches occur due to numerous unforeseen and uncontrollable events. All launch carrier payloads should plan to support a minimum of 4 launch attempts (96 hours) without requiring launch carrier access. The PD specifies all payload requirements for applicable launch delays. In the event that a launch scrub occurs for more than 8 hours, typically access to a payload is provided. Due to the criticality of operations required to re-establish the proper launch configuration after a delay, the PD should support delay scenarios as appropriate. For samples/hardware requiring access because of a delay, the ISS Program and the Space Shuttle Program determine if servicing/change-out is possible under the actual conditions. If servicing/change-out is agreed upon, the PD provides the necessary replacement items, personnel, and hardware.

7.1.7.2 Post-Landing and De-Integration

The PD must be prepared for several return-vehicle de-integration processes. These processes include the nominal post-landing process, the intact abort process, early end of mission, and ferry flight should the primary landing site not be available due to safety or other concerns.

The PD is responsible for any required ground servicing at the payload removal site to ensure the successful de-integration of payload hardware from the carrier transport system. Landing site processing may include pre-shipment inspection and limited power-on testing. The PD is responsible for participation in the payload removal activities and adds/modifies requirements, concurs on procedures, analyzes data, and makes engineering recommendations and decisions required by any conditions not within specifications. The PD arranges for all packaging, documentation, and transportation of the payload from the landing site. This includes the preparation of detailed packing lists identifying all components being shipped. Prior to packaging each item, a visual inspection is performed to identify the state of the hardware prior to transportation. In addition, all elements are weighed to obtain a final weight summary.

7.2 Sustaining Engineering

The FCF Utilization Team ensures that flight hardware and GSE meet program technical, schedule, safety, and performance requirements throughout the life of the hardware. The Sustaining Engineering Team ensures continuous successful operation of the integrated ground and flight segments. This includes conducting appropriate system analyses, data evaluations, testing, maintenance, and modifications of the FCF ground and flight hardware and software necessary to sustain on-going operations. Limited life items should be tracked for safety and/or mission success reasons, incorporating upgrades as required, standard reporting of the on-orbit payload performance, and developing trend analyses using on-orbit systems reports and other available data.

7.2.1 Ground and Flight Support Hardware and Software

The Sustaining Engineering Team is responsible for the on-going maintenance support for all FCF ground and flight support hardware and software; including simulators, EDUs, GIUs, Training Units, and all FCF hardware and software systems and components in the TSC. This includes maintenance of Commercial-Off-The-Shelf (COTS) hardware and software (licensing and support) to support the ground infrastructure. This ground infrastructure is used for purposes including, but not limited to: payload integration and verification testing, payload data acquisition, training of the crew and PD, and mission simulation support. The maintenance of the PRCU is performed per D683-27519-1, User Guide for the PRCU.

7.2.2 Ground and Flight Hardware and Software Configuration Management

The Sustaining Engineering Team provides CM for the development or modification of ground and flight hardware and software. Ground and flight hardware and software may be developed or modified to correct software faults, work around hardware failures, or provide additional system capabilities. The CM includes tracking the configuration of FCF flight elements, flight spares, and ground units; including the tracking of the configuration of FCF hardware in the TSC. The FCF CM system is described in the MRDOC Configuration Management Plan, MRD-PLN-0002, and the MRDOC Software Configuration Management Plan, MRD-PLN-0003. EDU, GIU, and flight configurations are managed using a database as part of the logistics function. This database is designed to track the metrics of all FCF ground and flight hardware; including configurations, use, upgrades, anomalies, maintenance, and software configurations.

7.2.3 FCF Integrated Logistics Support

The FCF Utilization Team provides integrated logistics support for the FCF, as documented in the FCF Integrated Logistics Support Plan, FCF-PLN-0033. This plan defines the integrated logistics support activities to be implemented during steady-state operations of the FCF on-board the ISS and addresses support for future FCF upgrades and payloads. Specifically, the FCF Integrated Logistics Support Plan defines all logistics activities necessary to support the development, procurement, maintenance, packaging, handling, storage, and transportation of FCF flight hardware, associated ground hardware, and support hardware throughout the project life. Implementation of this plan focuses on five critical areas:

- Engineering consultation on the logistics and maintenance aspects for the preliminary design of future FCF upgrades and payload development

- Logistics and supply support analysis including spare provisioning analysis; maintenance task analysis; operational availability modeling; repair level analysis; re-supply and return analysis; and perform supply support analysis

- Logistics and supply support including inventory management; packaging, handling, storage and transportation; tracking limited life items, reporting on-orbit system performance, and developing trend analysis based on available data

- Maintenance of ground and flight hardware including preventative and corrective maintenance; performing anomaly resolution, repair, refurbishment, maintenance and modifications for flight Orbital Replacement Unit (ORU) and ground support components for all hardware and software elements

- Development/Maintenance of on-orbit and ground maintenance procedures to support organizational and depot level maintenance for both flight and ground hardware, including GSE

8.0 OPERATIONS

The Operations process includes all documentation, hardware, and personnel support to assure that the FCF and its payloads operate as planned. This process begins with development of an Operations concept from experiment requirements, continues with operations integration including final procedure and display development and approval, operations training of both crew and GSP, on-orbit operations of both facility and payload, and ends with archival of data, as shown in FIGURE 22. The operations integration process involves detailed definition, thorough planning, proper development of operational capabilities, and comprehensive training that culminates in the proper execution of flight operations activities. The FCF Utilization Team is responsible for supporting real-time operations and all activities relative to the integrated payload configuration, starting in the pre-increment and working through the post-increment stages.

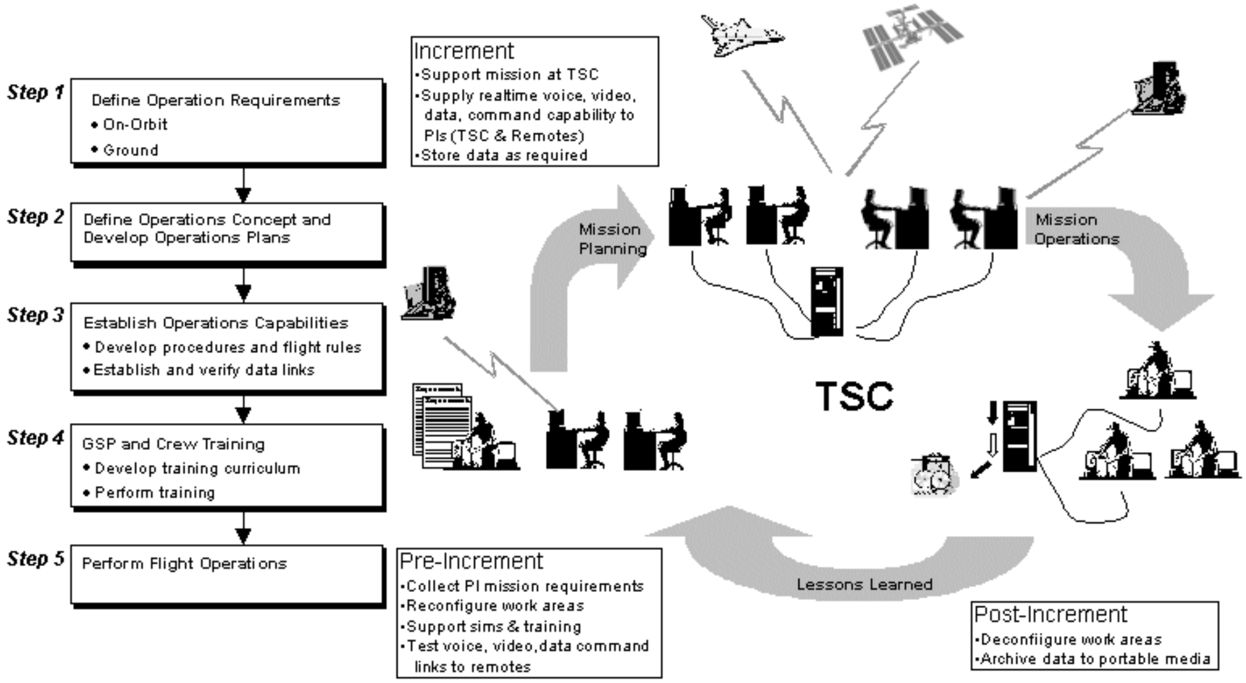


FIGURE 22 FCF PAYLOAD PRE-INCREMENT, INCREMENT AND POST-INCREMENT SUPPORT

The primary site from which the integrated FCF payload is operated is the GRC TSC. The FCF provides GSE enabling GSP to process and archive downlinked data, uplink commands, and access mission operations information. The Operations Cadre support for nominal integrated operations is two shifts per day, 5 days per week, but can be extended to three shifts per day, 7 days per week, when the FCF integrated payload is active or other planned operations are being performed. The Operations Cadre is formed to conduct increment operations and consists of payload, FCF and TSC provided personnel to support successful mission operations dependent on a particular increment's payload requirements. Members of the Operations Cadre can monitor an experiment's progress, either from the TSC or from a remote site, and can (if required) routinely uplink commands from the TSC. The primary activities and/or products of the Operations process are summarized in FIGURE 23.

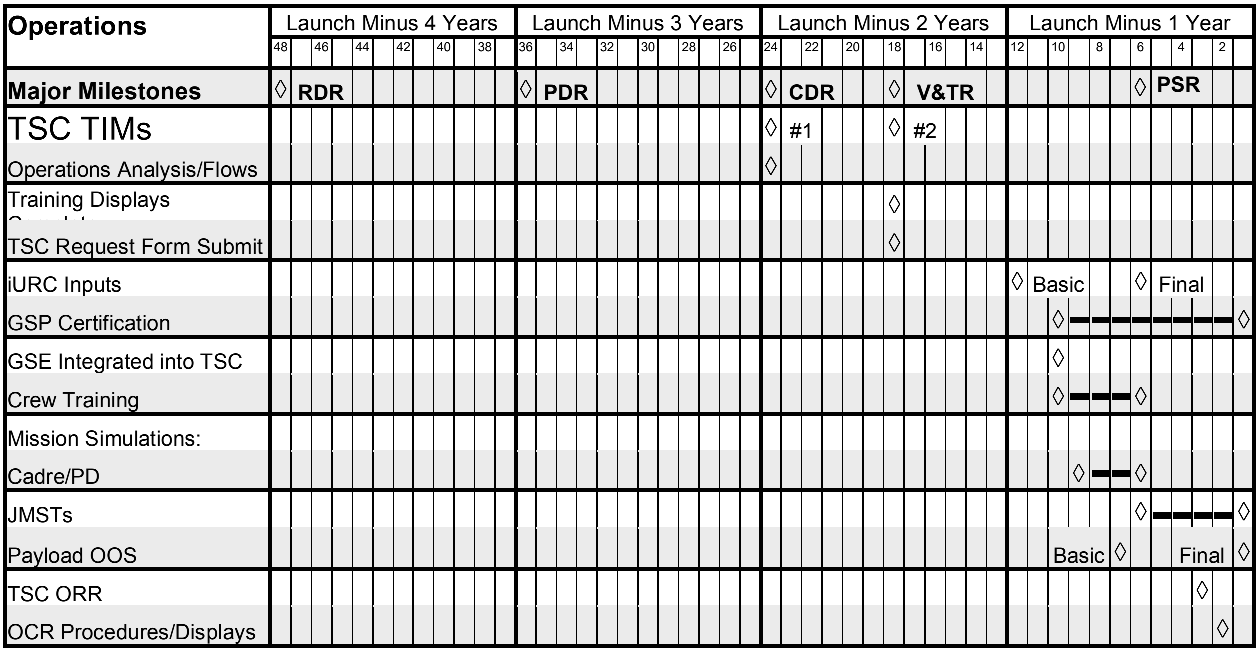


FIGURE 23 OPERATIONS ACTIVITY TIMELINE (TYPICAL)

The Operations Cadre is responsible for the planning and scheduling of all FCF integrated payload on-orbit operations, requesting all necessary ground and on-orbit resources, and implementing and following the planned integrated payload operations. Preparations are made to respond to any crew and ground team communications and off-nominal situations. Standard procedures are developed to resolve on-orbit problems or anomalies. The Operations Cadre provides the following mission operations support:

- Coordination of real-time payload and/or carrier requirements with the PI, PD, carrier, and other appropriate entities
- Acquisition, processing, and archival of real-time data
- Correlation of data with mission events, replanning and data analysis
- Preparation of data products for data dissemination and PI-specific mission summary reports
- Preparation of unique data analysis reports for the PI
- Provision of operational change, status, planning, and inputs from the ISS Program control center personnel
- Participation in any defined working group interchanges

8.1 Flight Segment Operations

A carrier transport system transfers FCF and payload hardware to the ISS. The crew, with support from console operators on the ground, performs a safety-oriented checkout of the installation and interfaces following transfer from the carrier transport system, installation, and connection to ISS systems. Payload hardware is designed to allow on-orbit removal and replacement to update the scientific capability. Some payloads may be unique to specific science objectives and be totally contained. On-orbit sample replacement or exchange capability as well as selected systems calibration by the crew is required. Safety verifications are conducted on-orbit after all configuration changes, as defined in the hazard analysis and safety compliance data package. Individual experiment sequences are automated and are capable of operating in an untended mode, but crew monitoring and intervention may be required.

The TSC is the hub for Operations activities. The TSC houses the console operators and provide telemetry acquisition, distribution, processing, and ISS video displays and voice communication capabilities for payload commanding. The data to be transmitted to the console operators consists of systems monitoring information such as temperature, power, and sample position, as well as video and other data essential to the operation of the overall facility and each specific experiment. Payload monitoring and science related data, as applicable, is available to those PIs at GRC or located at remote sites where off-site monitoring capability has been established. Data from the orbiting FCF is routed through the ISS C&DH System via the POIC to the TSC. All payload commands are nominally implemented through the TSC. Any commands identified as hazardous would be issued from the POIC. Operations must comply with NASA Security Policy, NPD 1600.2A. The Space Acceleration Measurement System (SAMS) and Principal Investigator Measurement Services teams at GRC provide acceleration measurement data to FCF users. FCF acceleration data is routed through SAMS.

8.1.1 Operations Preparation

Flight operations encompass all “on-console” processes required during real-time operations to manage, operate, and control the FCF and the scientific packages. Successful flight operations are the result of a well-planned and cooperative effort on the part of all participants, including the FCF Utilization Team (Integration and Operations Team subcomponents), who transition support to the Operations Team at payload launch.

8.2 Pre-Increment Support

The FCF Utilization Team provides operations support throughout the development and operations of the FCF integrated payload (payload/facility carrier) by participating in requirements development, design reviews, ground testing, and on-orbit support. All FCF payload requirements and timelines must be documented. PDs submit their support requirements through the FCF Utilization Team. Operations staff then evaluates all accepted increment resource requests to determine efficient resource allocation plans. The Operations staff develops, submits, and maintains Operations

Data contained within the PDL; including mission flight rules, payload regulations, launch commit criteria, payload messages, payload operations team structure, and ground safing procedures.

The FCF Utilization Team, in conjunction with the payload counterparts, must be prepared to respond to crew and ground team communications and be prepared for all off-nominal situations. Should the expected time on-orbit be extended, the PD can make use of the opportunity by either developing a contingency plan or using the OCR process. Standard procedures to resolve on-orbit problems or anomalies must be prepared. The FCF Utilization Team develops crew procedures and associated documentation for the integrated payload from the unique inputs from each PD on a particular increment. Following creation of the Payload Operations Data File (PODF), crew procedures are extracted and submitted to the Online Project Management System (OPMS). Crew procedures are validated prior to crew training via prototype, training unit, simulator, or other acceptable mockup. This team supports usability testing of the crew procedures. Additionally, this team coordinates with the PI, the facility/carrier organization, and various subsystem disciplines (e.g. electrical, thermal) to develop and submit inputs to the iURC system and maintain mission-planning information for the payload. Appropriate operations data is developed, submitted, and maintained within the PDL; including mission flight rules, payload regulations, launch commit criteria, payload messages, payload operations team structure, and ground safing procedures.

The Operations Cadre supports the increment-specific Payload Operations and Integration Working Group (POIWG) that is typically held every quarter. The POIWG is a forum for all ISS PDs to meet with people from the POIC and discuss increment-specific ISS operation topics, issues and concerns. At this meeting the user payload operations concepts and processes are developed, and teams are established to support ISS utilization for station-wide payload operations. The Operations Cadre also participates on the MSFC Payload Operations Control Board (POCB), which is responsible for baselining all operations requirements and subsequently developed products as overviewed in the following sections.

The Increment Operations Plan is developed beginning at I-8 months for each increment by the Operations Team and defines the GSP team required to support on-orbit operations. It describes timelines, data requirements, and additional internal operations details. The Operations Team develops console documentation as defined in the Flight Operations Support Plan, including Console Handbooks and a Ground Command Procedures Handbook.

8.2.1 Integrated Operations Requirements

Members of the FCF Utilization Team enter integrated operations requirements into the iURC/URC (User Requirements Collection) system. An FCF database collects and combines FCF rack-specific information from the FCF Utilization Team with the payloads data gathered from the PD. All data is submitted as low, medium, or high rate, as well as video link bandwidth rates, as defined and submitted in the Ground Data Services Data Set.

8.2.2 On-Orbit Operations Summary and Short Term Plan Development

The MSFC Mission Planning Team develops the On-Orbit Summary (OOS) (Basic, Final) for an increment at approximately L-6 months, based on inputs from the FCF Utilization Team. The Operations Cadre, which includes the PD, should review the OOS to ensure that requirements were reflected properly. Activities are listed for each day in the increment. No on/off times are assigned to activities planned in the OOS. During each weekly short term planning cycle, a 1-week portion of the OOS is updated 2-weeks in advance of its execution. The OOS update feeds Short Term Plan (STP) development. The week after updating the OOS, the mission planners generate an STP timeline by assigning on/off times to planned activities.

8.2.3 Payload Command and Control Interfaces

Commanding is accomplished via standard and custom displays, which are available at the TReK workstations, located at the TSC consoles. Each command is coordinated with the Huntsville Operations Support Center (HOSC) via voice loops. Commanding “windows” are timelined into the plans based on crew activity and Acquisition Of Signal (AOS) times. These times are estimates, so the voice communications with the POIC plays an important role in coordinating commanding activities.

8.2.3.1 Operations Analysis and Flows

The ISSPO strongly recommends that the PD use operations analysis or flows to define crew tasks before developing crew displays and manual procedures. This process should take place at I-24 months. Operations analysis or flows products may take the form of Operations Sequence Diagrams (OSDs), Decision/Action Diagrams (DADs), or other products. These products should describe both nominal and off-nominal experiment operations. Operations analysis or flows are used as a tool to efficiently develop payload crew displays and procedures. They are also used to support the development of training material.

8.2.3.2 Displays

ISS display and graphics standards are to be used by all ISS display developers. Payload-unique DADs and static and dynamic display prototypes are integrated by increment for the FCF to ensure uniform facility displays. DADs are used in the verification of both procedures and displays and represent the steps and decisions that must be accommodated to achieve a particular operation for an ISS payload. The Payload Display Review Panel (PDRP) must then approve these displays. Development of products is tied to the crew-training schedule for the payload, but is typically required by L-18 months. For ground displays, the PD can automatically generate a display (reference http://payloads.msfc.nasa.gov//trek/) to view any telemetry that the ground support TReK is processing. Actual deliverables can be negotiated with the PDRP, as defined in SSP-58700-ANX. Ground displays should be completed in time to support the ground training/simulation schedule for the payload.

Most Operations Cadre displays are developed for the TReK environment using the TReK Application Programming Interface (API) to provide presentation of rack and payload data. These displays are developed by the FCF Utilization Team and used in training and simulation exercises. TReK displays comprise the bulk of all ground displays. From these displays, the Operations Cadre can command and control the FCF and view downlinked telemetry data. In addition, a set of displays are developed that look like the crew's on orbit displays, which are JAVA based displays driven by a web browser, such as, Internet Explorer or Netscape Communicator. These displays can be used for tasks such as training, troubleshooting, ground testing, and rack checkout.

8.2.3.2.1 Ground Displays

The FCF Utilization Team and PD develop ground displays that include the on-board displays and the TReK workstation displays used to monitor the health and status of the rack and it's payloads, issue commands, and view telemetry data as it is down-linked from the ISS. Both types of displays can be used by the GIU for troubleshooting and interface verification purposes.

8.2.3.2.1.1 Crew Displays

FCF crew displays are a subset of the ground displays. All on-board displays are JAVA based web pages that are stored locally in the rack IOP software set. The displays are pushed to the Station Support Computer (SSC) and displayed using the SSC's browser (i.e. Netscape or Internet Explorer). PDs are required to develop any displays necessary to cover their operations. These displays must conform to FCF software rules. Unique payload displays can be uploaded from the ground or installed by the crew during a new payload installation or upgrade.

8.2.3.3 Commands

Each rack has external interfaces to ISS resources and networks internal to the rack. Commands and data routed to and from each rack are routed through the IOP. Routing information is part of the data. A detailed list of commands and protocols for each of the command interfaces can be found in FCF-ICD-0076, Software Interface Control Document, Appendix A.

The Operations Cadre uses these commands to provide instructions to a component of FCF or its payload hardware or a processor controlling that hardware. End-to-End commanding is defined as the process of issuing a command (instruction) from an origination site to some final destination processor. Some command origination sites are from the ground, while others are from on-board processors, and each can have different commanding scenarios. There are several possible command origination sites for FCF:

- POIC
- TSC
- SSC
- Payload MDM Executive Software (PES)

The destinations of commands are the payload or system processors on the space station. Consultative Committee for Space Data Systems (CCSDS) based protocols is used for the transfer of all commands and data between the ground and the ISS processors. Commands using the CCSDS are defined in the POIC Generic User Interface Definition Document (SSP 50305).

Each command database includes FCF and PD commands and is developed from inputs from the ISS Program and the assigned payloads for that increment. These inputs define the ISS systems and subsystems commands to be used to control ISS hardware. User inputs define payload-specific command data to be included in their database build that allows Partner Control Centers (PCCs) to control their operations from the ground. For each increment a project command database is developed to define each command structure, its associated data, and the applicable command attributes (nominal, critical, hazardous, etc.).

Command processing from the HOSC utilizes the Enhanced HOSC System (EHS), which is database driven. The POIC can uplink several different types of commands. First, the POIC creates an Operational Command Database (OCDB) that contains Predefined and Modifiable Commands defined by payload users and/or POIC controllers. Predefined Commands are those that were predefined during the database creation and are fixed both in data content and length. Predefined Commands cannot be modified during real time operations. Modifiable Commands on the other hand are those commands that were identified during database creation which are modifiable during real-time operations. Modifiable Commands can have modifiable data fields, a modifiable length, both modifiable content and length, or either fixed and the other modifiable. Before a Modifiable command can be uplinked, they must be filled with data and stored back to the OCDB. Commands can also be "grouped" or linked together. This grouping of commands is used to uplink several commands automatically and is initiated from a single keyboard entry. Predefined and Modifiable Commands are created, controlled, and managed at the POIC.

8.2.3.4 Procedures

Flight controllers, the on-board crew, and the on-board MDM automated procedure executor software utilize FCF procedures to operate and maintain ISS payloads. At about L-24 months, an interface from the Operations Team works with the PD to develop both PD-specific and integrated procedures that are submitted to the PODF as one Data Set. The crew requires validated procedures for pre-mission training activities. At approximately I-8.5 months, the FCF Utilization Team obtains agreement on the basic version of all supported payload procedures with the respective PDs. The PD assures that the procedures and validation records reside in the Payload Information Management System (PIMS) at I-7 months for the PODF Control Board approval. Final publication occurs by I-5.5 months, and an OCR must be submitted to make subsequent changes. Procedures and displays submitted by OCR are expected by I-2 months.

The procedures for each increment are at the FCF rack level, with each set of payload-unique procedures as a subset. Procedures for both nominal and off-nominal operations; including normal, alternate normal, quick response, malfunction, corrective action, and reference information, are developed and incorporated into the training material developed for each rack as well as for payloads. Procedures are provided for crew use to assist in the installation, calibration, cleaning, and general maintenance of all flight hardware. In addition, procedures are developed for some off-nominal conditions. The procedure development, verification, and validation process is documented in the On-Orbit Procedure Development and Validation Plan, FCF-PLN-1151. Updates to this plan are required for each increment in the I-16 months timeframe.

The Operations Team generates and integrates procedures for future increments. Procedure development is described in the SSP 58700. Crew procedures are reformatted for use with MPV, a tool used by the crew. Procedures are also entered into PIMS and reviewed by the PODF Control Review Board. The Training Strategy Team (TST) helps to decide what procedures need to be developed. The Operations Team starts with a task list for each rack and, with TST input, decides which tasks require procedures and how the crew should train on each of the particular tasks.

Validation of procedures is performed several times during their development. Early desktop validation ensures that nomenclature is correct, related procedures and hazards are called out, and overall accuracy is achieved. Final validation of procedures is performed on the highest fidelity hardware available. For early flights, EM and even flight hardware may be available for validation. For later flights, the GIU and payload hardware is used to validate procedures. A Validation Record (VR) documents that a procedure ensures proper and safe operation. Each procedure has a VR to document the associated validation activities. Where appropriate, multiple procedures may be validated with a single VR. A standard form is available from the PODF homepage.

8.2.3.5 Data and Commanding Interface

The TReK is a PC/Windows-based telemetry and command system that is used by scientists and engineers to monitor and control experiments located on-board the ISS. TReK provides both local ground support system services and an interface to utilize remote services provided by the POIC. For example, TReK can be used to receive payload data distributed by the POIC and to perform local data functions such as processing the data, storing it in local files, and forwarding it to other computer systems. Users can extend TReK capabilities by using the TReK API together with commercial software products to utilize local telemetry and command functions. TReK systems also provide multiple levels of test and checkout capabilities. TReK test and checkout includes a Stand-Alone training mode, an interface to a Suitcase Simulator system for flight tools checkout, and the ability to conduct interface tests with the POIC. TReK users have complete control over the customization of their systems. The TSC Information Technology (IT) staff has the responsibility for system configuration, system management, and security (IT and physical). Both rack and PDs develop custom software and displays to run on TReK workstations.

8.2.4 Photo/TV Scene List Creation

At approximately I-7 months, the PD obtains a list of the payload-unique photos and TV scenes required for non-science data (historical documentation, public affairs, operations, etc.) and update from the Payload Planning Data Set, excluding facility or payload-unique cameras used within Operations.

8.2.5 Payload Information Management System

As the increment operations phase approaches, data that was submitted and contained in the PDL and iURC are placed under more rigid CM in the PIMS to accommodate station wide integration as shown in FIGURE 24. The PIMS system is used for the generation, storage, modification, transfer, presentation, CM, and control of the US PODF procedures and change requests. The US PODF is available for downloading and/or viewing through the PIMS website. The US PODF includes procedures, reference information, and associated auxiliary information required for payload support. The US PODF includes nominal, maintenance, quick response, and malfunction procedures required for payloads, and associated reference information such as schematics. Information is placed into the PIMS Database and subsequently used by flight controllers to develop other ISS Program documentation.

The ISS Operations Data File (ODF) contains all procedures and reference information that support the ISS on-board operations and is developed from the data residing in PIMS. The ground controllers, the on-board crew, and the on-orbit procedure executer software needed to operate and maintain ISS systems payloads and attached vehicles under both nominal and off-nominal conditions use these procedures. Payload transfer, installation, and checkout procedures are all part of the ISS ODF.

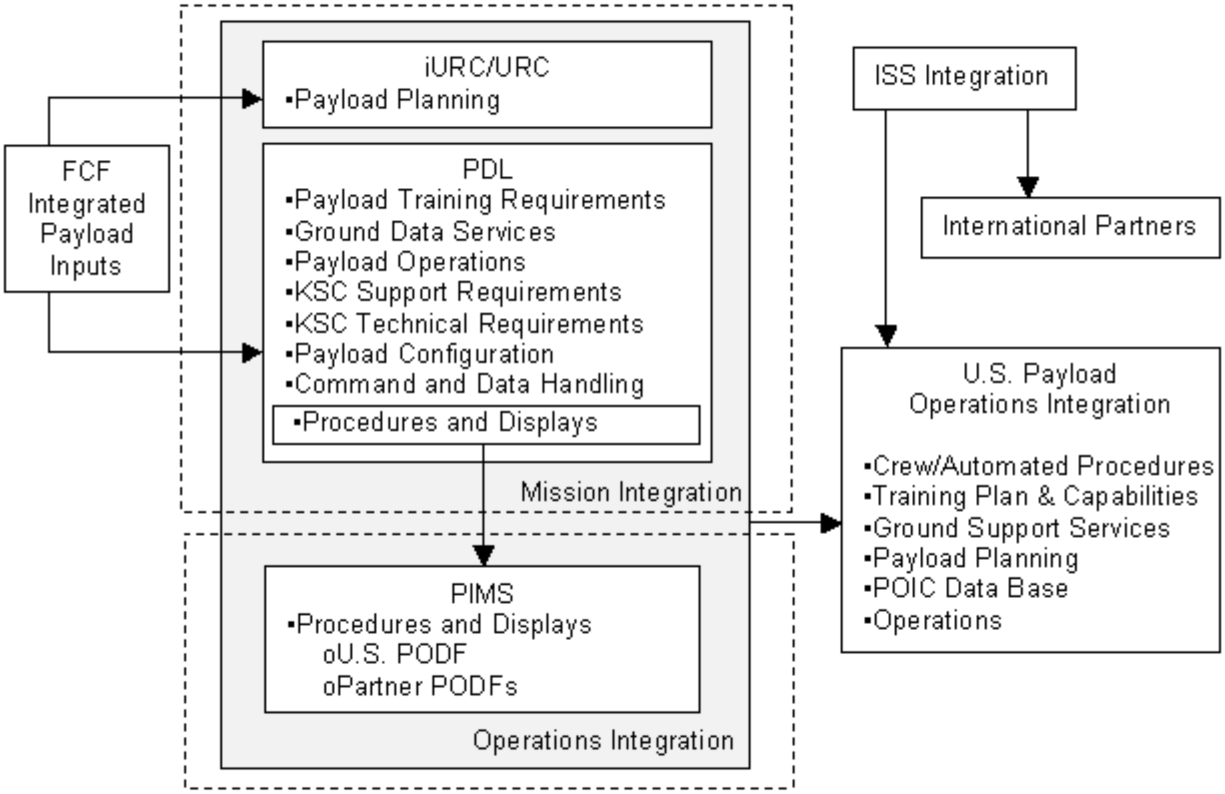


FIGURE 24 ISS PAYLOAD OPERATIONS INTEGRATION FLOW

8.2.6 Training, Simulation and Certification

The Training process is required to ensure that all GSP and ISS crewmembers are sufficiently trained to perform the integrated FCF payload mission objectives. GSP; including the Operations Team, the crew from the TSC, the PD, and selected PI personnel who are performing real-time operations, must be trained and certified to perform the required functions of their console position in support of the crew and payload. Certification takes place between I-10 and I-1 months. Payload training materials include the curriculum, lesson plans, training units, and computer based training. Other specific tasks performed under this process include training analysis and planning, training administration and implementation, training schedule development, instructor training and certification, complement simulation verification, training development and verification, and simulation planning and verification. For each increment, the FCF-specific training is supplemented with the payload-unique training. The Operations Team develops all training materials and tools required to train the crew and GSP.

The Station Program Implementation Plan - Training Volume (SSP 50200-07), and the Payload Training Implementation Plan (SSP 58309), drive the activities involved in the training process. The FCF Utilization Team provides a certified instructor to train all TSC users, TSC remote users and Operations Cadre. Classroom, workbook, computer-based training, and hands on training are conducted as appropriate for all personnel. The FCF Utilization Team will certify that all GSP at the TSC and any remote sites are trained for each increment. Systems certification is performed prior to the interface and system verification activities. Certification and verification are used as inputs to the CoFR process.

8.2.6.1 Crew Training

The FCF Utilization Team and the PD must support crew training. For each increment, the FCF-specific training is supplemented with the payload-unique training. The FCF Utilization Team works with the PD, the crew office, and the ISS training organizations to develop and implement the requirements for crew and ground training; including participation in the TST process. The PD, with FCF Utilization Team support, trains the crew on payload hardware utilizing the FCF training unit at the JSC. The FCF Utilization Team maintains qualified crew training personnel and performs crew training on the FCF based on crew rotation schedules.

The FCF Utilization Team provides the required crew procedures, lesson plans, documentation, and support personnel at JSC to train the ISS flight crew for FCF on-orbit operations. FCF training hardware and software supports all aspects of the required crew operations associated with the facility, except experiment-specific and ARIS/PaRIS operations. FCF PDs are responsible for providing training hardware and supporting experiment-specific crew training requirements. The ISS Program is responsible for training the ISS flight crew on ARIS/PaRIS operations. Payload component and integrated payload operations simulations complement the crew-training program, and prepare the FCF and payload teams for effective mission support. Computer-based training (CBT) is also used to familiarize the flight crew with FCF hardware and operations. The crew may receive this training on the ground or on-orbit. Ground crew training typically begins between I-10 and I-6 months. A typical crew payload-training template is shown in FIGURE 25.

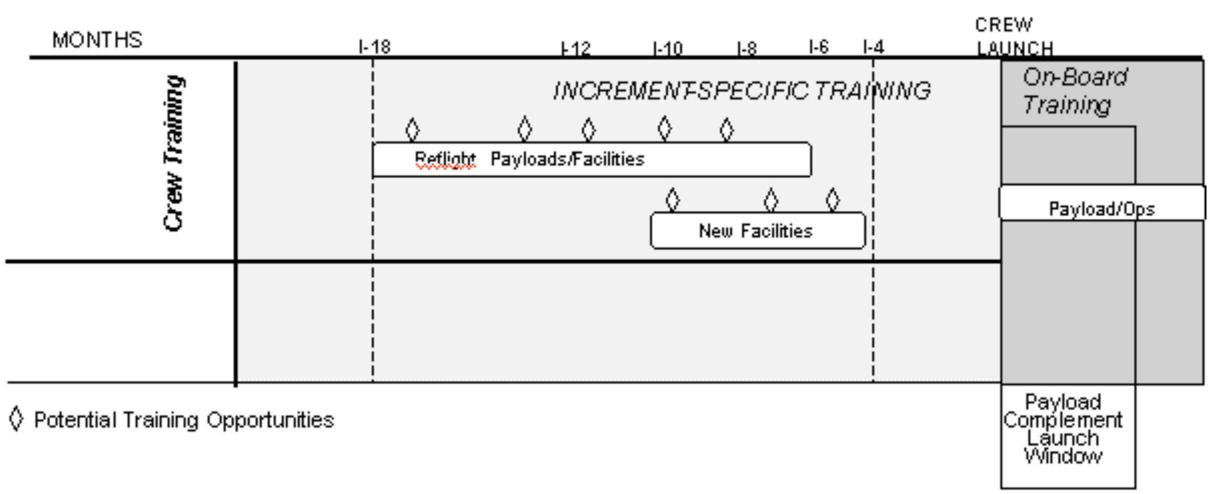


FIGURE 25 CREW PAYLOAD TRAINING

The ISS crew performs nominal procedures autonomous from the ground unless the PD employs specific procedure standards indicating otherwise. On-orbit crew training is possible, but it reduces the overall amount of crew time a payload has for hands-on operations. The training approach of the FCF Utilization Team is to implement an instructional development process that is requirements driven to ensure that only necessary training is conducted so as to make the best use of valuable crew training time, limited budget and shortened schedules. The FCF Utilization Team organizes training data for individual payloads into a single submittal with final approval by the PD. The FCF Utilization Team provides the PD with trainer requirements. The PD is required to participate in ongoing TST processes and is responsible for providing training materials for coordinated submittal to the ISS Program. Using the Payload Training Requirements Data Set (PTRDS) as an input through the MSD Payload Integration Website, the individual training objectives and lessons or types of training (briefings, hands-on, etc) to be conducted are developed. The FCF integrated payload support for the training process include:

- The definition of training requirements
- The development and presentation of familiarization and hands-on training lessons
- The timely delivery of both training and flight hardware
- Support of Payload Training Dry Runs at training minus two weeks

The Operations Team should have at least one crewmember that has a thorough understanding of the specific FCF increment goals and procedures.

8.2.6.2 Ground Support Personnel Training

The FCF Utilization Team works with the PD and the ISS training organization to develop and implement the requirements of ground team training. There are three types of GSP training validated by certification: TSC operations training, MSFC operations training, and FCF operations training. All GSP performing real-time operations must be trained and certified to perform the required functions of their console position in support of the crew and payload. Generic operations training, position-specific training, payload-specific (i.e., FCF/FCF payload) training, and ISS system-specific training is required. The FCF and payload teams provide payload-specific training and training associated with FCF ground segment operations hardware and software. Team members are identified at L-18 to L-12 months, and training begins at L-12 months and continues through L-3 months via simulations. The TSC staff is responsible for providing TSC-specific training. MSFC provides the training on HOSC/POIC hardware and software capabilities and services. JSC provides training on ISS systems. GSP also participates in payload training simulations to train, refine, and exercise console operators skills. These simulations include integrated FCF-payload and POIC simulations, and may include Joint Multi-Segment Training (JMST).

8.2.6.2.1 Telescience Support Center GSP Training

In preparation for real-time operations at the GRC TSC, the TSC Staff provides facility orientation, TSC voice and data systems training, and TSC security training to both staff and users. The TSC Training Manual (TSC-DOC-021) contains details on TSC-based training. Chapter 8 of TSC-DOC-016, the GRC TSC Operations Manual, contains the specific procedures reviewed during operations training. There are three types of GSP training validated by certification: generic operations training, position-specific training, and payload or ISS system-specific training.

The TSC Staff receives training in addition to the training provided for PDs in order to cover all facets of operations support; from changing toner in printers, to isolating and recovering from a fault in the real time audio system. Staff training includes operating and malfunction procedures for all hardware at the TSC as well as a review of the policies and procedures to handle both nominal and off-nominal situations that may arise.

The TSC Staff develops and maintains the GSP Training and Certification Plan, and maintains a status of the training completed for each person who is required to support on-orbit operations. Typically, at L-2 months the TSC Staff must certify that the TSC facility and Facility Operations Staff GSP are ready to support the payload ground operations through a formal CoFR process before a PD's hardware is launched. The Operations Team supports this activity for FCF and coordinate activities with the FCF subrack PDs. For more details, refer to the ISS Program Payloads Certification of Flight Readiness Implementation Plan, Generic (SSP 52054).

8.2.6.2.2 Marshall Space Flight Center GSP Training

The MSFC Team provides extensive training programs for Cadre, operations staff, and PDs, and for EHS and TReK use. Over 100 courses and tutorials are available to familiarize and train Cadre and PD members. A PD Training Academy has been designed with a subset of training courses tailored for the PD. A variety of mediums are used for training, including CD-based training and on-site training. Descriptions of PD courses offered can be found at the following site:

https://payloads.msfc.nasa.gov/station/gsptraining/pdcurriculum/pdcommand.html.

8.2.6.2.3 Fluids and Combustion Facility GSP Training

PD's operating within the FCF receive training from Operations Staff on facility operations; including a general capabilities overview, commanding operating procedures, Operating Staff interface procedures, real-time operating status retrieval, and any other operating procedures unique to conducting operations from within the FCF.

8.2.6.3 Mission Simulations

Simulations (SIMs) provide the opportunity to exercise skills learned during training. Each FCF PD participates in training as an FCF team member as follows:

- L-12 to 9 months: Internal SIMs. FCF uses this time to build proficiency in console operations, interfaces and products. Participation is limited to the Operations Team, PDs, and TSC Staff. Specific objectives are to:
  - Exercise the GSP members in console workstation usage
  - Exercise the GSP members in voice protocol

  - Exercise the GSP members in working voice and data interfaces
  - Exercise the GSP Team members in console procedures such as trouble reporting, Air-to-Ground procedures, payload regulations, flight rules, console handbooks, and shift handovers
- I-9 to 6 months: MSFC Cadre/PD SIMs. These simulations exercise the Crew (or crew surrogates) and GSP on the processes and procedures supporting payload operations. The MSFC is responsible for leading these simulations. The objectives of this type of simulation are to exercise payload-specific interfaces and procedures in a flight-like environment. Specific objectives are to:
  - Work POIC/science teams/crew coordination for each shift
  - Increase proficiency in nominal and contingency operations for the ISS crew and GSP dedicated to payload operations
  - Develop proficiency in crew and GSP payload-specific interfaces in a flight-like environment
  - Exercise GSP cadre/science teams/crew in procedures and output products
  - Exercise handovers
- I-6 months to launch: JMST (End-to-End with Crew or backups). This type of simulation is conducted to exercise the crew and GSP on processes and procedures supporting the ISS systems. The JSC leads these simulations. In some cases, interfaces and coordination between Space Shuttle and ISS are exercised. This simulation includes Mission Control Center Houston (MCC-H) and/or the Space Station Control Center (SSCC). This type of simulation is the most realistic example of real-time operations because the Payload GSP interfaces with all parties involved with the planned real-time operations. This provides more realistic operational scenarios, feedback from other GSP support, and provides systems-specific objectives that:
  - Increase proficiency in which the payload community can exercise interfaces with the ISS Crew
  - Exercise and validate JSC/MSFC interfaces during transport, transfer, and activation of experiments
  - Work crew/POIC/MCC-H coordination for each POIC shift
  - Complete checkout of all payloads
  - Exercise payload regulations and flight rules
  - Exercise handovers.

8.2.7 Data Flow Scheduling Overview

This overview addresses the process that produces the data flow plan, which begins with the OOS: a high-level summary that indicates payload and system activity occurrences, along with total resource distributions and usage on a daily basis. The OOS also summarizes weekly totals for activity occurrences and resource information. The Resource Definition Subsystem (RDS) is a daily breakdown of crew time, data, and energy distributions for each partner, per segment. Total ISS resource availabilities, amounts used for system activities, and net availabilities for payload activities are also indicated on the RDS. Using this system, planners can prepare for the efficient use of ISS resources. Operations preparation planning is based on a schedule that supports multiple releases of the Increment Operations Plan. The Increment Operations Plan is a repository of operations information on the World Wide Web available during the pre-increment phase of operations.

The details in the following subsections help operations personnel create successful increment operations plans, thus ensuring the maximum chance for mission success.

8.2.7.1 Operational Change Requests

During operations, OCRs are the Operations Cadre's main input to the near term plans, after inputs have already been given through the iURC. Once any document, including procedures and displays, is baselined by POIF, changes must be submitted via an OCR. OCRs may be submitted once the Mission, Operational Support Mode, and Project (MOP) for the flight become active, usually at about L-3 weeks.

8.2.7.2 Fixed versus Flexible Activities

The crew has requested as much flexibility as possible in performing activities. Activities with data requirements may be flexible or fixed. If an experiment has the only low rate payload MDM requirement to a bus, then this activity could be flexible. The ground could be configured to receive this low rate whenever it became active, so the crew could perform this activity at their leisure. Medium rate data could be fixed or flexible, depending on what the rate is and how it impacts the maximum PEHG rate at any time. A high data rate experiment would be classified as a fixed activity. The crew would have to perform this activity at the scheduled time or the system might not be configured or able to support the rate. Video could be flexible or fixed depending on the rate and any other video constraints (such as sharing cameras, camcorder requirements, etc.). The Operations Team takes this information into consideration as they plan increment operations to ensure the most flexible plan. Flexible activities ensure that changing on-board schedules do not preclude activities key to mission success.

8.3 Increment Operations

Increment Operations encompass all facility planning and "on-console" processes required during real-time operations to manage, operate, and control the FCF and the payload. The PD supports on-orbit integration activities, flight and data reduction, and experiment real-time operations for PI analysis as part of the Operations Cadre. This includes taking actions required to make changes to pre-mission products (i.e., procedures, resources, Command Plan, etc.) and support mission operations (i.e., installation, troubleshooting, maintenance, operation, removal, etc.). The Operations Cadre represents the PD for final approval and submittal of OCRs, and authors FCF-unique OCRs to accomplish science objectives. Flight Operations begin with the payload being removed from the launch vehicle and end with the payload being integrated into the return vehicle.

The Operations Cadre is responsible for the real-time operations and supporting activities of the FCF integrated payload in conjunction with on-orbit operations. They provide GSE, enabling GSP to process and archive downlinked data, uplink commands, and access mission operations information. A trained staff for console operations is provided as defined in the FCF Increment Operations Plan. Console operations for operations support could reach up to 24 hours per day when the FCF integrated payload is active or other planned operations are being performed unless otherwise specified by GRC MSD. The Operations Cadre is responsible for the planning and scheduling of all FCF integrated payload on-orbit operations, requesting all necessary ground and on-orbit resources, and implementing and following the planned integrated payload operations. Preparations are made to respond to any crew and ground team communications and off-nominal situations. Standard procedures are developed to resolve on-orbit problems or anomalies. FCF GSP provides science mission operations support including coordination of real-time payload and/or carrier requirements with the PI, the PD, the carrier, and other appropriate entities. They also acquire, process, and archive scientific real-time data, support the correlation of scientific data with both mission events and replanning, prepare data products for data dissemination and PI-specific mission summary reports, prepare unique data analysis reports for the PI, provide operational change, status, planning, and inputs with the ISS Program control center personnel, and participate in any defined working group interchanges.

Standard operating procedures (SOP) are developed for the Operations Cadre. SOP’s ensure consistent operations over the life of the facility. SOPs are developed for operations timelining, data retrieval, review of telemetry, operator event logging, start of shift procedures, end of shift procedures, data system interface and archival procedures, as well as references to other procedures in documents for interfacing with the POIC and TSC. Review of SOPs is part of Operations Cadre training.

During operations, the Rack Officers (ROs) handle the generation and submission of all OCRs for their respective racks by working with their PDs for required inputs, although the entire Operations Cadre is familiar with the use of the PIMS.

The Operations Cadre coordinates activities with the POIC using the established planning tools. The OOS is used by the POIC to generate the STP and On-board Short Term Plan (OSTP), which provide a schedule of the next two week’s activities. This feeds the Week Look ahead Plan (WLP), which provides more detail. The Task List, consisting of activities that can be executed as time permits within the crew’s normal workday, provides a list of additional items for the crew to accomplish. Changes to these schedules may only be requested through the OCR process, which the Operations Cadre accesses through PIMS. The RO is responsible for submitting the final OCRs to Payload Planning at MSFC. These schedules are key to ISS operations. They plan not only activities, but resources as well, including use of Ku and S-Band for downlink of data and uplink of commands and software. The FCF Increment Operations Plan is mapped to the OOS and STP. These internal plans, which should include contingency planning, include more detail on deployment of ground personnel and resources in support of mission operations. The ROs are able to use a combination of the Increment Ops Plan and the STP to map daily staffing and planning, including use of FCF and TSC resources.

8.3.1 Nominal Operations

Nominal operations, excluding maintenance, are typically performed with minimal or no crew involvement. Software and scripts uploaded from the PDs and FCF RO at the TSC provide the command set to perform nominal operations.

8.3.2 Off-Nominal Operations

Using diagnostic displays and commands from the TSC, the Operations Cadre can attempt to perform many off-nominal procedures in order to minimize crew involvement. The on-orbit crew can, however, perform off-nominal commanding and operations via the SSC. The crew typically performs off-nominal procedures after ground operations prove unsuccessful or unavailable. Off-Nominal crew procedures are usually performed on a rack that is powered down. The MPV is a station-supplied utility that provides the crew with procedures to perform both nominal and off-nominal tasks. The MPV interfaces with an ISS laptop, which does not require a powered rack for operation. The Operations Cadre can assist, in several ways, in troubleshooting. In addition, simulated SSC interfaces to the GIU, part of the ground infrastructure, can be used on the ground for troubleshooting and development of off-nominal procedures.

Off-Nominal operations are performed with the approval of the mission manager, and are based on recommendations by the Operations Cadre (including the PD) and other FCF GSP, as required.

8.3.3 GRC Telescience Support Center

The TSC is the hub for ground operations and telescience activities associated with the FCF. Telescience and operations facilities and capabilities are available to support fluids/combustion payload operations. The TSC provides the capability to execute ground operations of on-orbit ISS FCF payloads and systems in coordination with the MSFC HOSC, the JSC MCC-H, and other remote ground control facilities. Requirements for ground mission support are submitted through the MSFC-developed PDL. Ground data service requirements are defined in the Payload Ground Data Services Data Set using SSP 52000-PDS as a guide. User requirements for the TSC are submitted at L-18 months to the TSC using Form F4046, NASA GRC TSC Operations Support Request Form.

TSC Users must provide the TSC with a schedule of planned nominal operations and also provide updates so that the TSC can staff the facility accordingly. The PD is required to submit to the Operations Cadre a resource schedule on a weekly basis that forecasts FCF resource utilization for the following two weeks, and allows the Operations Team to conduct facility resource planning against changes and subsequent coordination with the POIC Cadre. The Operations Cadre also supports the PD in the Daily Science Tag up Telecons used by the ISS Program as a forum to work all on-orbit operations issues.

Approximately 40 percent of the operations area (Room 150) at the TSC is permanently devoted to supporting FCF real time operations, simulations, and training. Console areas are allocated to rack operations, payload operations, and GSE. The locations from which the rack and payload teams conduct both operations and simulations are shown in FIGURE 26. Once their hardware is set up at a console, PDs train, simulate, and operate from the same console location. This is shown in FIGURE 26.

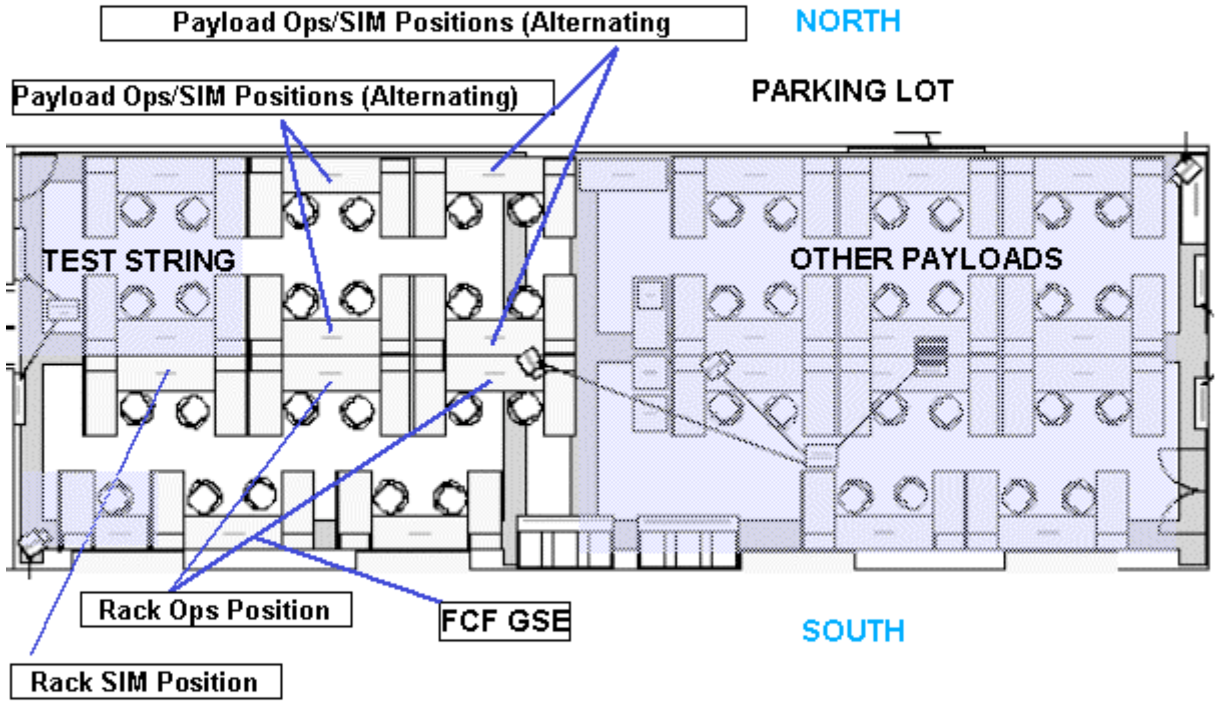


FIGURE 26 TSC OPERATIONS AREA

An operations console nominally supports two operators, as shown in FIGURE 27. It consists of two TReK workstations, a color monitor to view ISS video or other channels available from the TSC's video switch, an audio interface panel capable of accessing up to 48 audio loops and support for four headsets, a telephone, and two chairs. Shared services include printers and fax machines.

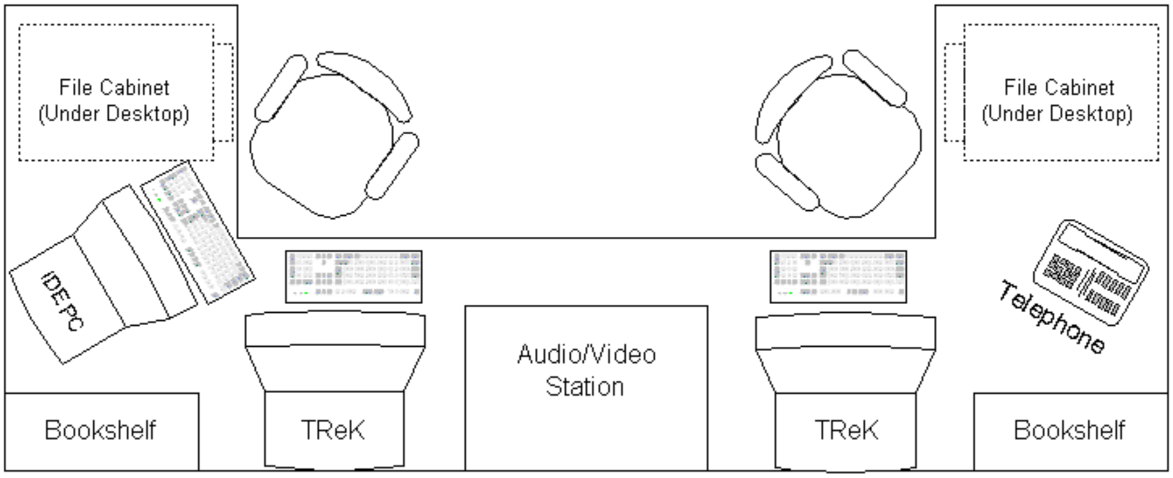


FIGURE 27 TSC NOMINAL CONSOLE LAYOUT

8.3.3.1 Lead Increment Scientist Daily Science Tag meeting

A daily teleconference is held with the Lead Increment Scientist Representative (located at MSFC) to review status of active payloads on-board the ISS. Upcoming ISS Program events, including new OCRs, anomalies, and status of ISS subsystems are also discussed routinely. Typically, representatives from each of the payloads active during the Increment participate in this meeting. For FCF, at least one RO and one representative from the PD participate in every meeting. A staff member from GRC TSC Operations also participates. Minutes from this meeting are generated and distributed on a daily basis.

8.3.3.2 TSC Kick-Off/Initial Payload Support

Technical Interchange Meetings (TIMs) are scheduled at L-24 and L-18 months to provide early support to PDs. TSC capabilities are defined so that the PD can determine the type of support to request. Each user identifies their intent to perform operations at the TSC by completing the “TSC User Request Form” which contains a list of questions that assist the project in early planning and scheduling of facility resources. Users are asked to submit the TSC User Request Form to the GRC TSC at L-18 months.

8.3.3.3 TSC Payload Developers Meetings

FCF PDs are encouraged to attend TSC/PD meetings to exchange important information concerning ISS ground operations. These meetings, which occur bi-weekly before, during, and after a mission, serve as a forum for users and the TSC staff to discuss issues, concerns and detailed information to ensure mission success. It is suggested that PD support of TSC/PD meetings start at no later than L-10 months. The TSC PD meetings are open to all FCF and TSC supported payloads and can be attended via teleconference by non-local PDs. This meeting is also a forum where TSC users can discuss their needs as they affect other users. The focus of this meeting is usually on TSC facility development, operations, and increment transition issues.

8.3.3.4 Payload Operations from the TSC

The TSC provides the following to the PD:

- Space and resources for PD – Including hardware interfaces, training, and simulation support.
- Facilities support – Including network, data, video, and audio.
- IT Services – Including payload data distribution, data archival (and playback), data recording (including video), reconfiguration, and remote site setup and support.

The POIC Payload Operations Handbook (POH) is available on the POIF website (reference http://www1.msfc.nasa.gov/POIF/). The POIC POH contains Payload SOPs prepared by the POIC Cadre. SOPs define the responsibilities, personnel interfaces and step-by-step operations. The TSC Operators Manual (TSC-DOC-016) is available at each console. It contains SOPs that are unique to the GRC TSC. The TSC user is expected to utilize these SOPs when conducting simulation and real-time operations within the TSC.

The TReK is used by the PD at the TSC to receive, process, display, record, and forward real-time and playback telemetry, uplink and update payload commands, perform local exception monitoring, local calculations, word processing, and file management, and control telemetry and command processing using local databases. TReK can also be used from a remote site with the same functionality as at the TSC with the exception of commanding. TReK software has the ability to download parts of the command and telemetry databases from a supporting facility database (either POIC or TSC) for the purpose of building local functionality at the TReK workstation (i.e. displays or command scripts). Mission execution and mission planning tools can also be accessed from a TReK system. TReK users have complete control over their systems, and as such also have responsibility for system configuration, display generation, system management, and security.

Under most circumstances, only the POIC is able to communicate with the crew concerning FCF payloads, and only during scheduled times. However, on a case-by-case basis, the PD may be allowed to communicate with the crew. Negative reporting from the crew should be the anticipated mode of on-orbit operations. It is assumed that operations are proceeding nominally and on schedule unless the crew reports otherwise.

8.3.3.5 Payload Timelining

Original payload timelines are provided to the ISS Program via the iURC as part of the Payload Planning Data Set within the Mission Integration process. Basic iURC inputs are due at I-12, and final inputs are due at I-6 months. From this input, the ISS increment-specific OOS is generated to support integrated ISS payload operations. The basic payload OOS development is due at I-6.75 months; final payload development is due at I-1.75 months. The basic and final integrated OOS are due at I-6 and I-1 months, respectively. The timelining interface during real-time operations for FCF PDs from the GRC TSC (or remote location) is through the Joint Execute-package Development and Integration (JEDI) website. This password protected website contains a calendar that provides a detailed plan for the ISS week. This plan reflects all changes to the timeline. Inputs into the weekly timeline are through the Daily Science Tag-up Telecon hosted at the TSC with Operations Cadre support or through the submittal of an OCR.

8.3.3.6 Payload GSE Within the TSC

TSC user areas are prepared to accommodate user provided GSE and the required TReK workstations. Interface and system verification activity, including data flows with the POIF, ensures that the implementation of the system design is complete. The PD/TSC User often has a need to utilize their own hardware to support operations. This hardware must comply with the TSC IT security plan (based on NPG2810.1) and must be integrated into the user's work area within the TSC, which should occur at I-10 months. All GSE that interfaces with any TSC system must be tested to verify nominal operation and to ensure that the integration does not negatively affect any TSC system. The User must submit a GSE Test and Verification Plan to the TSC prior to GSE integration. This Plan defines the objectives that prove that the GSE is operating properly, and defines the resources and methods required for testing the objectives. The TSC staff schedules POIC support (if required) for testing. All TSC users must submit access control request forms per the TSC Physical Security Plan.

8.3.3.7 Ground Data Management

The Operations Cadre utilizes both TSC and FCF provided hardware to manage all data received from on-orbit hardware. A data management plan should be followed to ensure capture, processing, and timely dissemination of all flight data. In addition, the Operations Cadre provides downlinked data to the CDS, so the data can be compiled with data retrieved from flight hardware and data from ground testing. This compiled Data Set is used for trend analysis, handover to the PI, permanent archival, etc. All data (telemetry, image, health & status, science) is downlinked using a CCSDS packet. For detailed information, see SSP 41154, US On-orbit Segment (USOS) to US Ground Segment (USGS) Command and Telemetry Document, General Command Packet format. Each type of data plays a unique role and is required to ensure complete mission success.

During mission operations, all FCF science and telemetry data is stored in a TSC-administered resource specifically designed for FCF and subrack payload data archival. A subset of this data is available to remote users via a web interface. The TSC provides the network architecture for these web pages, but it is the responsibility of each PD to provide the web page content. Web applications should be developed in time for simulations, starting at approximately L-7 months.

Image and video data can be received at the GRC TSC via the data stream as science data, via ISS video, or directly from the hard drives. The data streamed telemetry method allows for a richer, higher quality video source. From the ground, FCF payload operators can command the download of image data. This data set would be a subset of all the on orbit video data saved, presumably to view interesting or more significant events during an experiment run. ISS video provides a more real-time display of data with less resolution. The return of the flight hard drives from ISS preserves all science data unless deletion of data is commanded from the ground. All data retrieved from returned flight hardware, video included, will eventually be integrated into the mission data archives. FCF flight hardware is capable of processing image data on orbit. Lossless compression of video data to maximize downlink bandwidth efficiency is planned. Additional science specific processing may also be performed.

Image data on the ground will be subject to, at minimum, archival into a database. Data will also be subject to science specific post processing and possibly further reduction. Science and telemetry data will be post processed and archived into an on-line database for presentation and analysis. The database will be capable of managing data for a minimum of 90 days. In addition, previous increments will be archived into a system that allows for retrieval and restoration to online systems. Although all data will be retained, data relevant to science will receive special attention and be associated with it's particular experiment run. Using this method, data deemed "not interesting" (by the PD Team) can be more quickly archived, conserving online resources and consequently allowing for a richer set of online science and trend analysis data.

8.3.3.8 Central Data System

The CDS compiles data from the major locations as shown in FIGURE 28. The CDS File Store provides a database for all FCF-related data. CDS provides a current Data Set, which can be archived to tape (or use other suitable long term storage media) for permanent storage and archival. The GRC Computer Services Division (CSD) handles the permanent storage and maintenance of this media.

All data generated from FCF flight and ground hardware must be archived. Data is collected at four (4) major locations:

- Flight Hardware On-Orbit
- GRC TSC
- GIU
- EDU

Trend analysis is performed on both flight and ground data as part of the Sustaining Engineering function. Examination of health and status data is used to facilitate maintenance of all FCF hardware, including refilling of bottles, diagnostic hardware generation, and hard drive capacity, as well as overall system performance over time. In addition, science data is compiled and can be handed off to the PI.

8.3.3.9 TSC Data Systems

The GRC TSC provides a local infrastructure to support interfaces to ISS for Rack Operators and PDs. From the TSC, the Operations Cadre can command and control FCF activities on-board the ISS. In addition, they can downlink science data, as well as health & status data. The TSC also supports an architecture that allows for secure access to science data via the Internet, as shown in FIGURE 28.

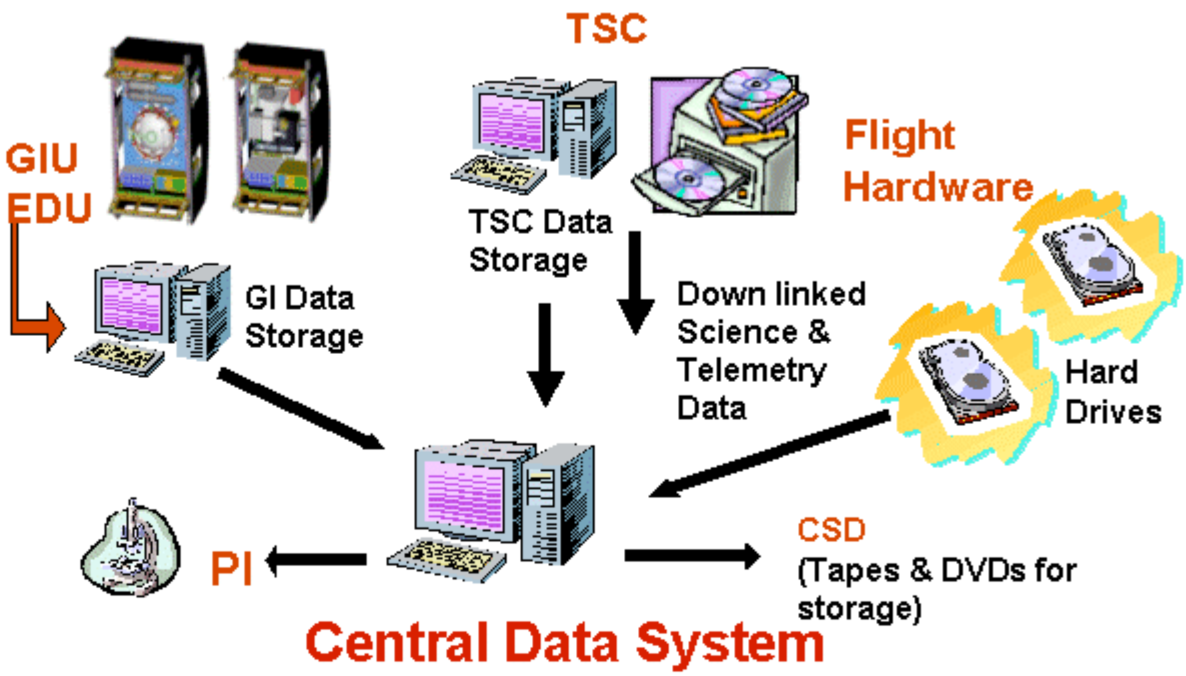


FIGURE 28 FCF CENTRAL DATA SYSTEM AND MAJOR INPUT SOURCES

8.3.3.10 Science Data Distribution

Data Sets are moved in near real-time to a database that can be viewed from the Internet (via a secure connection), providing PI's and other interested parties not located at the GRC TSC with current information on FCF activities. TSC users design their own web sites to disseminate their data. The TSC staff works with the users to integrate the web sites into the system. The architecture used to accomplish this task is in place today and is used by Principal Investigator Microgravity Services. See http://pims.grc.nasa.gov for an example of this architecture in use.

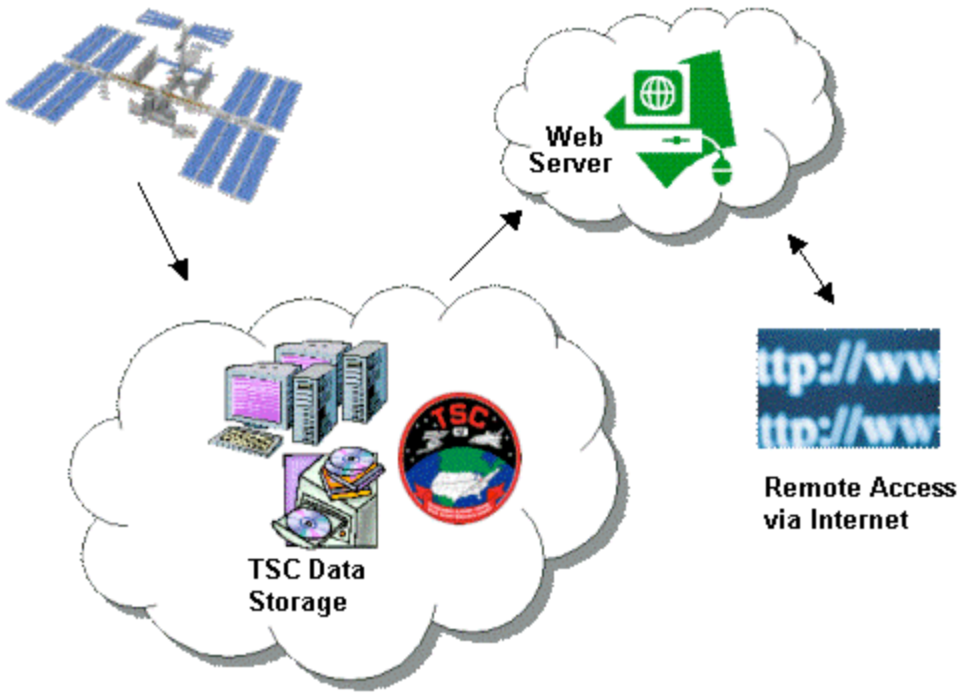


FIGURE 29 FCF DATA ROUTED TO THE INTERNET

8.3.4 Operations Readiness Review

At L-3 months, the TSC conducts an Operations Readiness Review (ORR). The purpose of this review is to verify that the TSC is ready to support increment operations for new payloads. Additionally, new and/or updated subsystems coming on line for the first time are also reviewed for operational readiness.

The main inputs to each ORR are new or updated payload-unique TSC Operations Requirements documents for each group of users. These documents detail operational requirements of the TSC to support a particular user group during their increment(s) of operation. These documents define not only payload requirements, but also new/unique TSC interface requirements to the HOSC, NASA Integrated Services Network (NISN), and GRC networks. In the event that no new requirements are generated for an increment, the review is not held. Products from this review can be used in support of the CoFR. Products to be reviewed include the Operations Requirements Compliance Matrix, Verification Reports (of new/upgraded systems), and Engineering Change Orders (ECOs) relating to new/updated systems.

8.3.5 On-Orbit Trend Analysis

Sustaining Engineering, as part of the Engineering Team, performs trend analysis on downlinked telemetry to ensure that maintenance is scheduled in a timely manner and that all systems are performing nominally. On-orbit trend analysis is part of an overall FCF program of trend analysis on FCF hardware. Metrics, defined by the Engineering Integration Team, are collected and added to the CDS and stored as part of the FCF history database, which contains a record of the use of all flight and GIU hardware. The data collected leads to better maintenance prediction and possibly aid in failure prediction and analysis. Trend analysis begins with the first rack turn-on and continues for the life of the facility.

8.3.6 Operational Scenarios

This section is provided to describe FCF/HOSC/TSC team interactions and procedures followed during real-time operations under given sets of circumstances.

8.3.6.1 Payload Transition

Increment transition is a time for a currently operating payload to end operations and a new payload to begin operations. For ground operations, payload operators from both the current and future payloads are trained and ready for operations at the TSC. The current payload would be available to assist in any crew shutdown/deinstallation activities.

The TSC Operations Staff works with the Operations Cadre to develop increment transition plans. HOSC-supplied software patches and upgrades are typical during this period, as is participation in HOSC CoFR testing required of the HOSC by JSC.

During some transitions, no change takes place at the TSC. However, changes to the EHS database require that TSC staff and users participate in CoFR activities to verify their data definitions and interfaces using the new database. The process usually lasts several hours.

During transition, payloads that are ending operations begin the process of vacating the TSC. This may involve physically moving GSE and materials from the TSC Operations Room, as well as removing data from the FCF servers. Payloads have up to 30 days after the end of their mission (de-orbited) to remove their data.

8.3.6.2 Ground Operations

Ground operations are a coordinated effort amongst the entire FCF GSP (Operations Cadre, PDs, Sustaining Engineering, etc.), the TSC Team, and the HOSC. The Increment Operations Lead is responsible for all activities. The Operations Lead follows the FCF increment Operations Plan; integrating any OCR's that have been submitted to PIMS.

8.3.6.3 On-Orbit

The crew's interaction with FCF is designed to be minimal, but assembly, maintenance, reconfiguration, and troubleshooting may require interaction with the crew. The Operations Cadre remains on-console during any and all on-orbit activities, including rack assembly by the crew. On-console personnel are available to answer questions and, if the rack is powered, monitor telemetry from the rack to ensure nominal operation.

The crew and Operations Cadre do not usually speak directly. Their communications are coordinated through the HOSC. When the crew is performing a procedure on the rack, they typically use MPV to perform a procedure. The Operations Cadre may be able to view the procedure being executed if ISS video is available during this activity.

8.3.6.4 Payload Operations (Typical)

The Operations Cadre is on-console during all payload operations. The RO reviews schedules weekly to determine times that the FCF consoles must be staffed. During a normal day of operations, Operations Cadre members begin their daily shift by reviewing the Cadre log entries and (optionally) meeting with the previous shift Cadre. This is particularly important during a sustained operation or test run.

If a new experiment run is beginning, the RO announces his/her presence at the HOSC. Daily AOS/Loss of Signal (LOS) predictions usually vary from published times, making it important for the HOSC to know that the Operations Cadre is on-console and ready to begin commanding. Once the HOSC is aware that the Operations Cadre is ready to begin planned operations, last minute changes to the AOS/LOS timeline can be coordinated with on-console personnel.

Normally, all rack switches are in the ON position. Assuming this is the case, the RO can command the rack to turn on from the ground in coordination with the CPO. Once the rack has been turned on, the RO executes checkout procedure(s) designed to ensure that the rack is operating nominally.

At this point, the RO can turn over commanding to the PD, who begins a similar process of powering on and testing hardware in preparation for executing a scheduled experiment run. After all tests are completed, the PD commands the FCF to run an experiment.

Test runs range in duration from hours to weeks. The Operations Cadre staffs the consoles as long as the flight hardware is powered. When an experiment completes, data is normally saved on on-orbit hard drives. The Operations Cadre, often working with the PI, develops a list of experiment data to download to FCF ground data storage systems. The Data Management Officer (DMO) works with PDs and ROs to retrieve targeted data from the flight hardware and, once received, verify its integrity. Data verification is primarily an automated process to determine that all “pieces” of a requested file have been received. Based on the results of the automated analysis, the DMO and PD jointly decide whether data should be retransferred in part, in whole, or not at all. On-orbit resources are also examined after experiment runs to determine if data needs to be saved or can be deleted in preparation for the next experiment.

8.3.6.5 Troubleshooting

One method of troubleshooting on-orbit anomalies is to attempt to reproduce the event or condition on the ground. If an FCF payload has a set of hardware on the ground of sufficient quality and fidelity, that hardware can be integrated into the GIU in Building 333 at GRC. This type of troubleshooting requires that all resources (GIU, PD hardware, PRCU, GSP) are available to perform the test. The rack configuration, both hardware and software, would be extracted from the history database in the CDS and duplicated in either the GIU or the EDU. The TReK simulator or SSC, depending on the conditions, could be used to facilitate the ground test. FCF CM ensures that software and hardware configurations match on-orbit configurations.

Once completed, data from the ground test is analyzed and compared to flight data in order to discern the type of problem. A test report and action plan may be required, depending on the nature of the test and resulting data. Software patches and hardware configuration changes may be designed to correct the anomaly, and can be tested using ground hardware/software prior to implementing changes on orbit, saving crew time and other valuable resources.

8.3.6.6 Maintenance Impact to Flight Operations

Efficient on-orbit maintenance is the major driver to achieving effective on-orbit FCF hardware operational availability. The availability of FCF and associated components is primarily dependent on failure-rate and secondarily dependent on resupply and/or spares delay.

Two types of on-orbit maintenance are used; organizational on-orbit maintenance and on-orbit intermediate maintenance. Organizational on-orbit maintenance is conducted by the ISS crew and is limited to removal and replacement of ORUs, with some cleaning, calibration and sub-ORU parts replacement as justified by the repair-level analysis. On-orbit intermediate maintenance relates to tasks performed on-orbit by the ISS crew members on FCF flight hardware removed from the hardware's installed location, and is limited to diagnosis and isolation of malfunctions, repair of hardware by replacing defective modular components, repair of cables, application of authorized repair kits, and verification that functions have been restored. Intermediate maintenance may be preferred, for example, to replace a cable harness on an ORU located in such a position that access to the harness may be difficult. Maintenance tasks are worked into the appropriate Flight Operations Support Plan to ensure that all required maintenance is planned during each increment.

8.3.6.7 On-Orbit Checkout and Acceptance

Initial FCF increment mission results consist of data from on-orbit checkout of FCF racks after their installation in the US Laboratory and after the first experiments have been conducted in the racks. This data is analyzed and presented at Readiness and Acceptance Reviews (R&AR) planned approximately four months after each FCF rack is deployed to the ISS. An Integration Manager, who is a civil servant appointed by GRC to oversee the mission, is responsible for managing and coordinating all activities associated with ISS FCF initial increment operations. The RO is responsible for rack checkout on orbit. Extensive rack checkout is performed after initial installation into the ISS and each time the rack is reconfigured. Procedures for rack checkout are generated for each checkout activity in order to test all functionality, new and existing, with each configuration. The RO supports the development of these plans and procedures along with the PD as part of increment preparations. A nominal rack checkout procedure is performed each time power is applied to the rack. This procedure is less exhaustive, but verifies all major rack interfaces and functions are working and that the rack is ready for operation. Results from Power On Self Tests (POST) from each of the computers in the rack are included in this procedure. The POST data is downlinked and stored in FCF data storage systems at the TSC and eventually be moved to the CDS database for archival and trend analysis. These tests are tailored to the configuration of the rack in order to properly test rack operation.

The GRC FCF Project Manager, Fluids and Combustion Facility Scientists, Payload Project Managers and Scientists, and the Increment Manager supports any post-increment mission debriefings associated with initial FCF/payload operations. Publication of the final experiment results is the responsibility of each PI. Increment Mission Analysis Reports are prepared by the Project Manager (or designate) following the completion of each increment of payload operations during the steady state operational phase of FCF. These reports are used to identify improvements in operations and reduce potential problems in future mission configurations, as well as highlight lessons learned from the increment. Archival copies of data from on-orbit and ground-based science operations and testing are created and delivered to PDs.

8.4 Post Increment Activities

TSC post-operations activities involve actions that must be performed in order for the TSC user to complete their ground operations at the TSC. This may include the removal of the TSC User GSE, recorded data, and/or removal of the GSE from their work area so that the TSC can prepare for the next increment operations. Users are required to vacate their work area following the end of the increment or as negotiated with the TSC initially via the TSC Request Form, then as agreed to via the Ground Data Services Data Set.

8.4.1 Post Flight Data

FCF payload experiment data is image intensive. Additional data, not down-linked to the TSC, is recovered from flight hard drives when they are de-orbited and returned to the payload team at the completion of a mission. The PD integrates this additional data into the CDS, where a final, complete set of data can be compiled and turned over to the Principle Investigator. A complete set of data is also archived to permanent media and passed on to the GRC CSD team for storage.

8.4.2 Permanent Data Storage

The CSD at GRC provides a mechanism for the long-term storage and maintenance of FCF rack and payload data. The Operations Team creates and hands over permanent storage media to the CSD at regular intervals, nominally at the end of each increment. The Operations team works with CSD to create a Memorandum of Agreement pertaining to the transfer and storage of archived FCF data.

APPENDIX A - Abbreviations and Acronyms

Scope
This appendix lists the abbreviations and acronyms used in this document.

Acronym	Description
AOS	Acquisition of Signal
API	Application Programming Interface
ARIS	Active Rack Isolation System
C&DH	Command & Data Handling
CBT	Computer-based training
CCSDS	Consultative Committee for Space Data Systems
CDR	Critical Design Review
CDS	Central Data System
CG	Center of Gravity
CIR	Combustion Integrated Rack
CM	Configuration Management
COC	Certificate of Compliance
CoFR	Certification of Flight Readiness
COTS	Commercial-Off-The-Shelf
CPO	Command and Payload Multiplexer-Demultiplexer Officer
CR	Change Request
CSD	Computer Services Division
DADs	Decision/Action Diagrams
DCM	Diagnostics Control Module
DMC	Data Management Controller
DMO	Data Management Officer
ECO	Engineering Change Order
ECR	Engineering Change Request
EDU	Engineering Development Unit
EHS	Enhanced HOSC System
EMI	Electro-Magnetic Interference
EPCU	Electrical Power Control Unit
FCF	Fluids and Combustion Facility
FCF-PI	Microgravity Science Glovebox – Principle Investigation
FIR	Fluids Integrated Rack
FIVT	Final Interface and Verification Testing
FOMA	Fuel/Oxidizer management Assembly
FRR	Flight Readiness Review
GIU	Ground Integration Unit
GN2	Gaseous Nitrogen

Acronym	Description
GPVP	Generic Payload Verification Plan
GRC	Glenn Research Center
GRHF	Ground Rack Handling Fixture
GSE	Ground Support Equipment
GSP	Ground Support Personnel
HOSC	Huntsville Operations Support Center
HRDL	High Rate Data Link
HW	Hardware
I-	Increment Minus
IA	Integration Agreement
IAR	Increment Acceptance Review
ICD	Interface Control Document
IDD	Interface Definition Document
ILS	Integrated Logistics Support
IOP	Input/Output Package
IPLAT	ISS Payload Label Approved Team
IPSU	Image Processing and Storage Unit
IRD	Interface Requirements Document
IRR	Increment Readiness Review
ISS	International Space Station
ISSPO	International Space Station Program Office
IT	Information Technology
JEDI	Joint Execute-package Development and Integration
JMST	Joint Multi-Segment Training
JSC	Johnson Space Center
KSC	Kennedy Space Center
L-	Launch Minus
LCC	Launch Commit Criteria
LMM	Light Microscopy Module
LOS	Loss of Signal
LPA	Launch Package Assessment
MCC-H	Mission Control Center - Houston
MDCA	Multi-User Droplet Combustion Apparatus
MDM	Multiplexer-Demultiplexer
MIP	Mission Integration and Planning
MIUL	Material Identification and Usage List
MOP	Mission, Operational Support Mode, and Project
MPV	Manual Procedures Viewer

Acronym	Description
MRDOC	Microgravity Research, Development, and Operations Contract
MSD	Microgravity Science Division
MSFC	Marshall Space Flight Center
MTL	Moderate Temperature Loop
MUA	Material Usage Agreement
MV	Main Volume
N2	Nitrogen
NASA	National Aeronautics and Space Administration
NISN	NASA Integrated Services Network
NSTS	National Space Transportation System
OBRD	Optics Bench Rotation Device
OCDB	Operational Command DataBase
OCR	Operations Change Request
ODF	Operations Data File
OMRS	Operations and Maintenance Requirements Specification
OOS	On-Orbit Operations Summary
OPMS	Online Project Management System
ORR	Operations Readiness Review
ORU	Orbital Replacement Unit
OSD	Operations Sequence Diagrams
PAH	Payload Accommodations Handbook
PaRIS	Passive Rack Isolation System
PCC	Partner Control Center
PD	Payload Developer
PDL	Payload Data Library
PDR	Preliminary Design Review
PDRP	Payload Display Review Panel
PEHG	Payload Ethernet Hub/Gateway
PES	Payload MDM Executive Software
PI	Principal Investigator
PIA	Payload Integration Agreement
PIM	Payload Integration Manager
PIMS	Payload Information Management System
PIRN	Preliminary Interface Revision Notice
PMIT	Payload Mission Integration Team
POCB	Payload Operations Control Board
POD	Payload Operations Director
PODF	Payload Operations Data File

Acronym	Description
POH	Payload Operations Handbook
POIC	Payload Operations and Integration Center
POIF	Payload Operations Integration Function
POIWG	Payload Operations and Integration Working Group
POST	Power on Self Test
PP	Planning Period
PP-	Planning Period Minus
PRCU	Payload Rack Checkout Unit
PRP	Program Requirements for Payloads
PSR	Pre Ship Review
PTCS	Payload Thermal Control Simulator
PTRDS	Payload Training Requirements Data Set
PVP	Payload Verification Plan
R&AR	Readiness and Acceptance Review
R&R	Re-supply and return
RDR	Requirements Definition Review
RDS	Resource Definition Subsystem
RFA	Request for Action
RO	Rack Officer
RPWG	Research Program Working Group
SAP	Science Avionics Package
SCR	Science Concept Review
SDP	Safety Data Package
SIM	Simulation
SOP	Standard Operating Procedure
SORR	Stage Operations Readiness Review
SSC	Station Support Computer
SSCC	Space Station Control Center
SSP	Space Shuttle Program
SSPF	Space Station Processing Facility
STEP	Suitcase Test Environment for Payloads
STP	Short Term Plan
STS	Space Transportation System
SW	Software
TCO	Timeline Change Officer
TGHR	Time-critical Ground Handling Requirements
TIM	Technical Interchange Meeting
TReK	Telescience Resource Kit

Acronym	Description
TSC	Telescience Support Center
TST	Training Strategy Team
URC	User Requirements Collection
US	United States
USGS	United States Ground Segment
USOC	User Support and Operations Center
USOS	United States On-orbit Segment
V&TR	Verification & Test Results
VDS	Verification Data Sheet
VES	Vacuum Exhaust System
VR	Validation Record
VRS	Vacuum Resource System
WLP	Week Look ahead Plan

APPENDIX B - GLOSSARY

Increment (I) - The duration of a typical crew rotation. A reference to I-32 would indicate that the payload milestone is expected to occur 32 months prior to the beginning of the Increment. Increments are also numbered sequentially, but begin with zero instead of one. In the early years of the ISSP, during the assembly of ISS, only two or three increments are accomplished in a Planning Period, and initially the Planning Period is not the length of a calendar year.

Launch (L) - A reference to L-12 would indicate that the milestone is due 12 months before the actual Launch (L) of the Space Shuttle that pertains to the payload.

Multi-Use Experiment Hardware – An insert or attachment to a science facility, such as FCF, that accommodates a series of experiments. It typically provides power, heat rejection, illumination, measurement and diagnostics capabilities. Examples of Multi-Use Experiment Hardware for the GRC-developed FCF include the Multi-User Droplet Combustion Apparatus (MDCA) for the CIR and the Light Microscopy Module (LMM) for the FIR.

Payload - Experiment Hardware, an experiment that operates within Multi-Use Experiment Hardware or a stand-alone experiment that operates independent of Multi-Use Experiment Hardware.

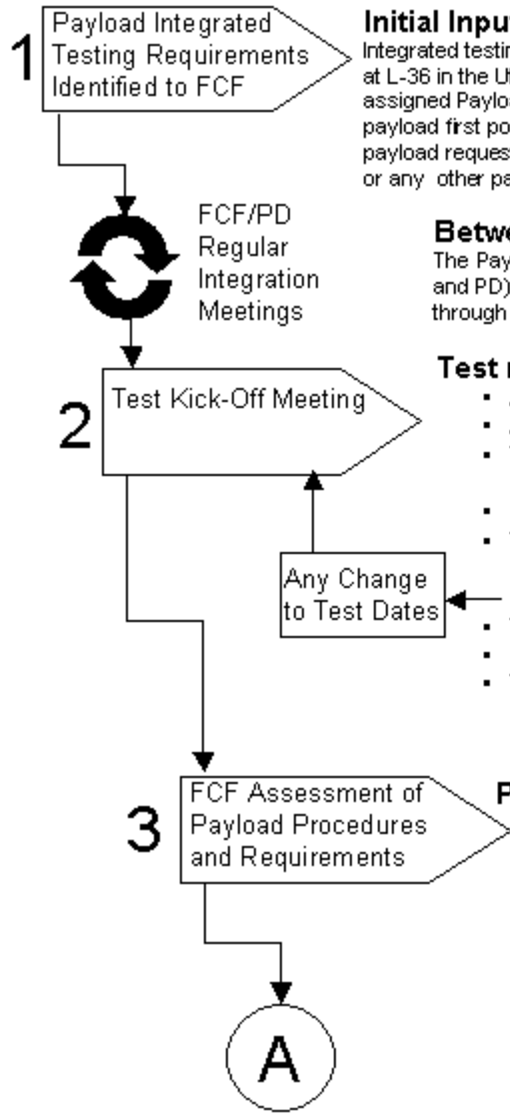
Planning Period (PP) - A PP is a calendar year for which a number of Increments are identified. A typical PP of the fully assembled ISS consists of four three-month Increments. Time references using "PP" indicate that a milestone is to be complete relative to the beginning of what the ISSP calls a PP. Therefore, a reference to PP-48 would indicate that a payload milestone is to be completed 48 months prior to the beginning of the PP. PPs are numbered sequentially, beginning with one.

Increment Planning Data Set - This data is used for verification and confirmation of resource availability for all payloads planned for a given increment.

Training Strategy Team – The structured planning and decision-making group who determines the payload training requirements for each payload or experiment and the complements of payloads or experiments as part of the TST process. The official membership of the TST consists of MSFC training personnel, JSC training personnel, SVMF/PTC Subject Matter Experts (SME), PD Representatives, Crew Representatives, and Program Office personnel.

APPENDIX C - Integrated (Payload/FCF) Test Process

Integrated (Payload/FCF) Test Process



Initial Inputs collected from the Payload at PDR and negotiated through CDR:
Integrated testing requirements are documented at a top level as part of the FCF Payload Integration Agreement (IA Main Volume) typically at L-36 in the Utilization schedule specific to each FCF science payload. Changes to initial inputs are coordinated through the FCF-assigned Payload Liaison who functions to identify and coordinate all FCF planning and integration activities and deliverables (science payload first point of contact). The FCF Engineering Integration Lead that functions to maintain ground processing functions reviews payload requests against FCF EDU and GIU (and Flight Unit for first flight payloads) usage schedules to avoid conflicts with maintenance or any other payload or facility testing conflicts.

Between CDR and Test minus 8 weeks:
The Payload Liaison participates in Integration Meetings with the PD at least monthly (frequency determined between Payload Liaison and PD); providing the PD with the opportunity to refine testing requirements. Changes are identified, coordinated, and approved through changes on the payload-unique Utilization schedule.

Test minus 8 weeks

- An FCF Integrated Test Lead is assigned by the FCF to coordinate the specific test and lead the overall effort.
- A Payload Test Lead is assigned by the PD to coordinate with the FCF Test Lead.
- The PD provides detailed requirements for test and payload-specific procedures including defining any hardware installation and handling procedures required to conduct the test.
- FCF Payload Liaison maintains log of requested tests, and assigned leads.
- The FCF Engineering Integration Lead provides status of the FCF EDU or GIU* (as appropriate) integrated usage schedule against the planned test time frame. Any issues or conflicts related to adjusted testing priorities are worked through a NASA GRC FCF Government representative.
- Test success criteria is identified to be documented later in the Integrated Test Procedure.
- FCF and payload subsystems are assessed for readiness for upcoming tests (pre-constraints meeting).
- The Required Test is assessed against Area Safety Permits in place for EDU and GIU* operations. If the requirements levied are outside of the current permits, the FCF Engineering Integration Lead immediately applies for a change of permit through the appropriate GRC Area Safety Committee (takes 4- 6 weeks).

Post Kick-Off Meeting to Test minus 6 weeks

- FCF Integrated Test Lead assesses payload requirements against FCF requirements and procedures to successfully implement the integrated test.
- FCF Engineering Integration Lead assesses PRCU and Building 333 readiness if required and coordinates status to FCF Integrated Test Lead.
- FCF Integrated Test Lead develops an Integrated Test Schedule that contains all of the critical path items required for both the FCF and the Payload to make the test a success. This schedule is then maintained by the FCF integrated Test Lead and included as part of the Integrated Test Procedure.
- The draft constraints list is established and maintained by the FCF Integrated Test lead.

**Note: Process applies to any Integrated Test involving the usage of FCF EDU, GIU, or Flight Units (for initial payloads), including fit checks.*

Integrated (Payload/FCF) Test Process

A

4 Integrated Test Plan development

Test minus 6 weeks through Test minus 4 weeks

- The FCF Integrated Test Lead develops the Integrated Test Procedure.
  - ➢ The payload-provided procedure is integrated with facility procedures.
  - ➢ Test procedures will include test success criteria, Integrated Test Schedules, FCF hardware and software configuration definitions, personnel requirements for both FCF and payload support, and validation of personnel certification if required to run tests (PRCU, laser, crane, tow motor, etc.).
- The Integrated Test Schedule and an initial assessment of readiness status (including review of constraints) is coordinated between the FCF Integrated Test Lead and the Payload Test Lead.
- The status of all FCF components required to meet test requirements is completed.
- Any issues or conflicts are worked informally between the FCF Integration Test Lead and the Payload Test Lead.

5 Payload Informal Review and Comment

Test minus 4 weeks

- The Integrated Test Procedure Draft is put out for review by the Payload Test Lead.
- The Payload Test Lead finalizes solutions to all issues or comments with the FCF Integration Test Lead.

6 Constraints Meeting

Test minus 3 weeks

The following are assessed or completed:

- FCF hardware and software readiness
- Payload hardware and software readiness
- Area Safety status
- Ground support hardware and software status
- Availability of critical personnel
- Unresolved issues (worked through NASA GRC FCF and payload Government representative)
- The FCF and payload both sign the Integrated Test Procedure
- Constraints are signed off; actions are assigned to disposition any final constraints

7 Test Team Meeting

Test minus 2 weeks

- Disposition of all final constraints occurs.
- Test team roles and responsibilities are coordinated, including FCF, payload, Quality Assurance, any Government participation, Safety etc.
- FCF functionality is checked out prior to test.
- The FCF EDU or GIU is configured to fulfill test requirements (hardware and software).

B

B Integrated (Payload/FCF) Test Process

8 Run Test

9 Daily FCF and Payload integrated Test Tag-up Meetings

Daily (as required)
- Changes to the Integrated Test Procedure are coordinated and documented.
- Changes are assessed and any new constraints are identified.
- PRACA issues are worked:
  - Payload anomaly – Payload Test Lead writes payload-specific PRACA
  - FCF anomaly – FCF Integration Test Lead writes FCF-specific PRACA
- Any unresolved issues or conflicts are worked through the NASA GRC FCF and payload Government representative.

10 Post Test

Test Plus 1 Week
- FCF hardware and software are returned to "base" configuration.
- Consult database for differences between flight hardware/software performance against EDU or GIU Integrated Test performance.
- The FCF Integrated Test Lead coordinates any performance adjustments with the Payload Test Lead.
- An Integrated Test Report is drafted for review by the Payload Test Lead with inputs from the FCF Integrated Test Lead.

Defined Roles & Responsibilities

FCF Payload Liaison – Assigned by the FCF to a payload to identify and coordinate all FCF planning and integration activities and deliverables and serve as the PD first point of contact. Responsible for operation of FCF subsystems during test operations.

FCF Integrated Test Lead – Assigned by the FCF to be responsible for the end-to-end conductance of an integrated test with a payload. Has overall responsible for test success, hardware/software configuration, integrated test schedule, integrated test procedure development, and issue/constraint coordination/resolution. Responsible for any FCF PRACAs.

Payload Test Lead – Assigned by the payload to represent and coordinate test requirements with the FCF Integrated Test Lead. Represents the payload during testing to assure that procedures are followed and that any issues, conflicts, or changes are resolved/coordinated. Has overall responsibility for payload inputs including requests for FCF hardware/software configuration, input into the integrated test schedule, payload test procedure development, and issue/constraint resolution prior to test. Responsible for any payload PRACAs. Responsible for operation of payload subsystems during test operations.

FCF Engineering Integration Lead – Provides detailed technical guidance in the area of FCF interface and physical integration. Supports FCF integration and checkout including FCF GRC Ground Processing, PRCU maintenance and support, maintenance and application for Area Safety Permits, NASA building 333 facility utilization and integrated EDU/GIU testing schedules.